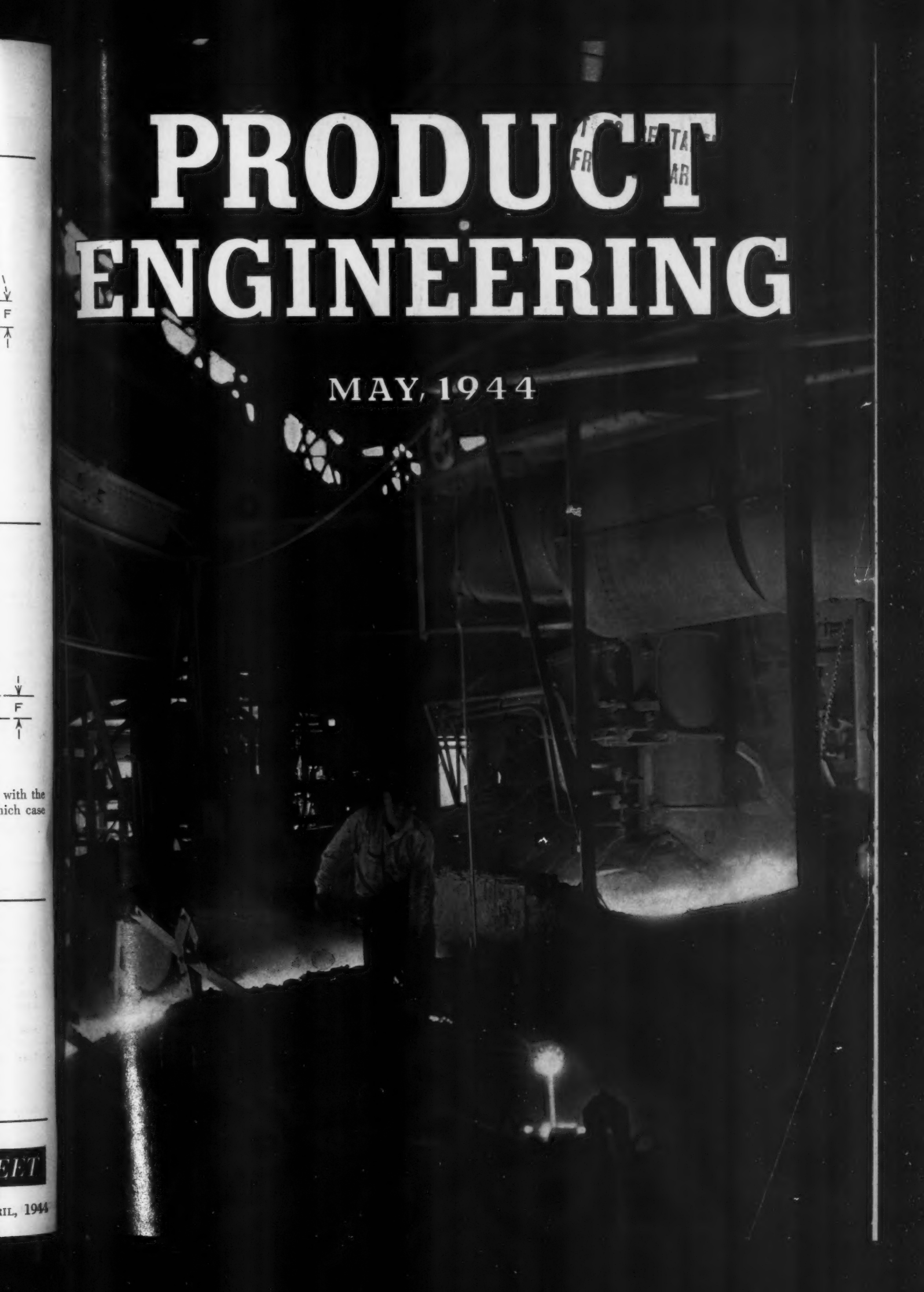
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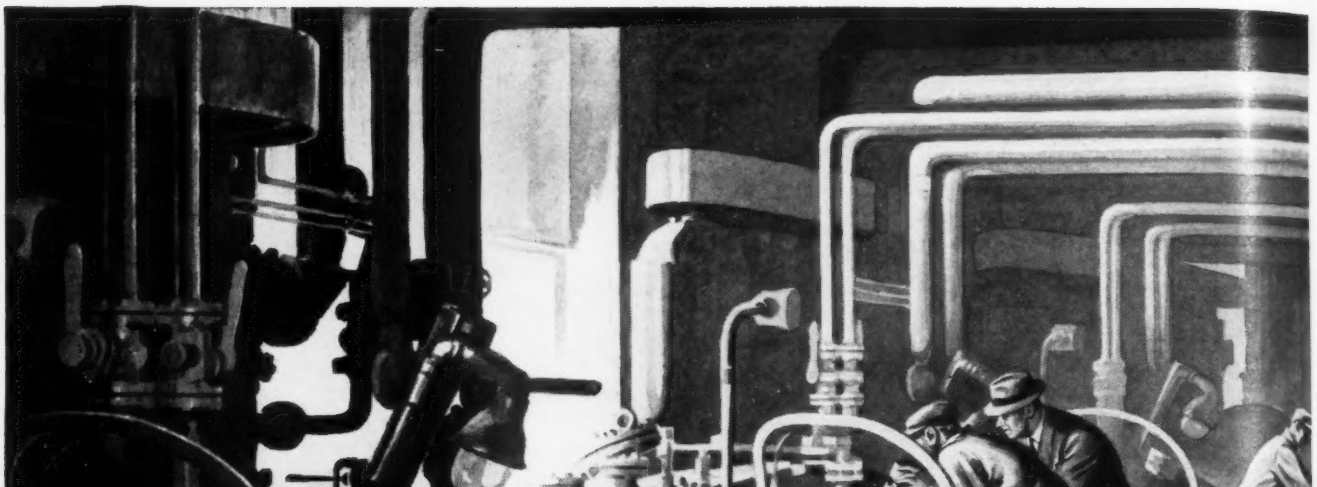
MAY, 1944



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Subscribers may encounter delay in receiving their copies of PRODUCT ENGINEERING. Such delay is caused by wartime strain on transportation and postal systems, a situation beyond the Publisher's control.

IN THIS ISSUE

Cover Picture courtesy Jones & Laughlin Steel Corporation, Pittsburgh.

Engineers Must Be Salesmen

The opportunities engineers have carved for themselves incidental to their jobs in designing war equipment will undoubtedly affect the future careers of many of them. In his punchy article page 289, Paul G. Hoffman, president of The Studebaker Corporation and chairman of the Committee for Economic Development, analyzes the position of the engineer and shows how the engineer can proceed to make himself "a man of business."

Precision Castings

A method of casting metals and alloys to such close dimensional tolerances that machining operations are eliminated or greatly reduced is offering design engineers new possibilities in the production of intricate parts and in the fabrication of alloys that are unmachinable or extremely difficult to machine. Most important war applications are parts for the turbo-supercharger and gas turbines using materials having high heat resistance. See page 293.

Curing Laminates With Dielectric Heat

For thin sections of non-conducting materials, heated platens provide a satisfactory means of curing. With heavy sections, however, cure is not uniform and time cycles are long. Uniform

cure regardless of thickness and considerable savings in molding time can often be achieved with high-frequency heating. A comparison of dielectric heating with other forms of heating is presented on pages 299-301 by R. W. Auxier of the Westinghouse Research Laboratories.

Shortcuts for Trial Samples

Speed in developing new designs represents an important factor in preparing for post-war markets. John Younger of the Ohio State University, discusses on page 302 his views on how simultaneous operations can eliminate time-consuming motions in preparing test models and finished products.

Stress Distribution At Openings in Fuselages

Third article in the series in which the problems encountered in aircraft fuselage analysis have been discussed and supplemented with practical approximate methods of solution. In conclusion, Gail Swan, chief of structures, Kaiser Cargo, Inc., Fleetwings Division, see page 316, describes some arbitrary approximate methods for calculating the distribution of primary and secondary stresses in spars and structures made discontinuous by cut-outs.

Calculator for Hydraulic Pressure Drop in Tubing

Usually it requires struggling with complicated charts and filling reams of paper working out involved formulas to determine the best size of tubing for a given task. This time-consuming burdensome job can be greatly simplified through the use of a new calculator developed by J. Jerome, hydraulic research engineer, Consolidated Vultee Aircraft Corporation, see page 319. The simple device, which is not commercially available but should be, adapts a slide rule technique to what in the past had been a cumbersome chore for the hydraulic engineer.

Lithographic and Electrolytic Template Reproduction

Last of a series on all methods of reproducing templates, the article beginning on page 327 describes several methods involving lithographic and electrolytic principles. One interesting aspect of this article is that two of the methods described were developed in England and are not yet very well known in this country.

New Steel-Aluminum Bond

Success in applying thin aluminum coatings to sheet steel spurred investigation of a method for bonding heavy aluminum sections to heavy steel sections and other metals and alloys. The investigation resulted in development of the Al-Fin process, used primarily for making aluminum-finned cylinders for aircraft engines. The process is described on page 333.

Silk-Screen Marking

Volume production of aircraft made necessary a swift process for marking signs, placards and instruction plates. One method that has gained considerable prominence recently is the silk-screen process. It is discussed on page 345 by F. A. Truden, process engineer, Nashville Division, Consolidated Vultee Aircraft Corporation.

Effect of Clearance On Bearing Performance

Procedure for predicting the performance of bearings often involves many theoretical considerations which lead to complicated equations and solutions. While not belittling such methods, L. M. Tichvinsky, U. S. Naval Engineering Experiment Station, see page 323, discusses the usefulness of the clearance ratio as a design factor in determining the lower and upper clearance limits in bearings for several types of machinery.

Joggle Design

One of the details involved in designing sheet-metal parts is fitting the parts to other members of an assembly. Since a certain amount of overlapping is almost inevitable where several sheet-metal parts are to be joined, perfect fitting often necessitates "joggling" the mating surface. Frank M. Mallett, Curtiss-Wright Corporation, presents a systematic design procedure for joggles on page 338.

Electrical Properties Of Plastic Materials

The electrical properties of plastic materials are covered in an article beginning on page 329, insofar as they serve their ultimate purpose—that of providing an efficient serviceable part. This is the second in a series of articles on plastics part design prepared by W. S. Larson of the General Electric Plastics Division.

WHAT'S COMING

Smaller War Plants

The Smaller War Plants Corporation was established by Congress to help small manufacturers contribute more effectively to the war effort by the "production of war and essential civilian goods." Maury Maverick, who is in charge of the Smaller War Plants Corporation, has now established a "Technical Advisory Service." The purpose of this service and its operation will be explained by Mr. Maverick in an article to appear in the June number.

Electric Controls for Present and Post-War Products

Chief function performed by electric controls is the making and breaking of electrical contacts, or otherwise connecting and disconnecting current carrying elements in electric circuits to govern the operation of electric motors, relays or solenoids. Next month's 16-page special section will describe the function, construction, operation, applications and new developments in the design of switches, relays, timers, thermostats, temperature and pressure regulating devices, and also arrangements used for torque, speed and sequence control of motors. This section is another in a series of special presentations appearing every other month.

Analysis of Inertia Forces In Reciprocating Engines

Engineers whose work involves applied dynamics will be interested in the semi-graphical method described by M. F. Spotts, Northwestern Technological Institute, see page 340, for determining the magnitude and direction of inertia forces acting in a one-cylinder reciprocating engine. This is the first of two articles on the subject.

Pneumatic Circuits—II

Since schematic diagrams of possible and actual applications of pneumatic circuits often give the best idea of the various ways in which they can be used, pages 336-337 present a series of such diagrams with brief explanations of their operation. These diagrams are a continuation of a similar group published last month.

PRODUCT ENGINEERING
MAY, 1944

Paul G. Hoffman, nationally known business leader, attributes much of The Studebaker Corporation's success to "sales-minded" engineering leadership. His chief engineer, W. S. James, is S. A. E. president. Mr. Hoffman is shown making the acceptance speech as Studebaker was awarded the Army-Navy "E".

Engineers Must Be Salesmen To Gain Business Recognition

PAUL G. HOFFMAN
President, The Studebaker Corporation
Chairman, Committee for Economic Development

An analysis of the opportunities presented to design engineers in their war contributions to show how they can capitalize on their experiences to qualify for positions of greater business responsibilities in company operations.

A CONSIDERABLE portion of the credit for industry's remarkable achievement in the war effort rightly belongs to the design engineers. A full accounting will have to be deferred until the war has ended because the job of developing designs of ever-better fighting equipment is one that will not slacken until the last shot has been fired. Tentative designs on drawing boards, experimental units undergoing tests in laboratories and new models being analyzed in combat service testify to the continuing vigor of our design and manufacturing activities and to the amazing qualities of the fighting equipment now in the course of development. This must not be taken as a reflection on our present materiel. We have complete confidence that it will prove its merits in the first large-scale crucial test of our fighting men and equipment.

A striking picture of the power of American engineering design and production is presented by the record of accomplishments. It has been less than four years since the United States launched its intensive war production program. In that short space of time our engineers have outstripped the Germans in spite of their ten-year head start. As has been demonstrated repeatedly, we have matched or excelled

Assembled at drafting boards, engineers such as these men plunged into strange fields of product design in developing the fighting equipment of war. They benefited from conferences with representatives of the customer—the U. S. Government.

Design merit is often not immediately discernible to a layman's eye. The engineer who can discuss intelligently the advantages of his design and the costs involved stands the best chance of having his point accepted.

every piece of fighting equipment the Nazis have used against us. Our uncanny detection devices and offensive weapons have all but wiped out the enemy submarine menace. Automatic range finders and gun aimers have robbed the enemy plans of most of their effectiveness.

In the Pacific theatre of operations, Japanese losses in planes shot down in combat are six to our one. The ratio of battle casualties is of the order of twenty to one. Our submarines are steadily wiping out the Japanese navy and merchant marine. Such performance cannot be fully explained by the superiority of our fighting personnel. Our equipment must also be correspondingly better. Our design engineers have every right to feel proud of the job they have done and will continue to do until complete victory has been won. It has not been an easy job and it is one which will demand the utmost in sweat and talent until the last detail is finished. The job is not only the design of entirely new equipment but also the development of new models and continuous improvements in the design of details in existing equipment.

In all this work, the design engineers of industry had unstinted help and guidance from officers and engineers of the military services concerned. Without such cooperation, or rather coordinated effort, it would have been impossible for the design engineers of industry to have made the record they did. The Army Air Corps, Navy Bureau of Aeronautics, both Army and Navy Ordnance, Signal Corps and the other bureaus and departments contributed. The results demonstrate the effectiveness of direct contact between the customer and the engineering design executives.

It is an axiom that one cannot do a worthy job laudably without being rewarded in some manner or other over and above the financial return. If nothing else, the pride of accomplishment creates self confidence and thereby is reflected in a strengthened personality. In addition, noteworthy accomplishments usually are instrumental in presenting new opportunities which, if recognized and acted upon lead to bigger fields of operation, increased authority and a higher prestige in the business world. These facts are now being demonstrated in the careers of many junior and senior design executives, ranging from chief draftsmen to vice presidents in charge of engineering.

In the intensive program of developing designs of war equipment in the shortest possible time it was necessary for many engineers to plunge into strange fields of product design. The manufacturer of automobiles found himself faced with the job of contributing to the detailing of the designs of trucks, jeeps, guns, tanks and airplane parts. Stove manufacturers undertook the design of field kitchens, food machinery manufacturers developed amphibious tanks, and railroad equipment builders contributed to the design of gun mounts, tanks and special cars. The list is virtually endless.

Obviously, American designers learned a great deal about materials, types of construction, service requirements and many engineering techniques. Many of them also experienced a training which will be far more valuable than the additional technical knowledge they absorbed, valuable as that may be.

For the first time, many design executives, especially those in the classifications ranging from chief daftsman to assistant chief engineer, had the opportunity of dealing directly with representatives of the customer. In their contacts, these engineers experienced the effectiveness of close relations with the customer and the business values resulting therefrom. They witnessed and participated in transactions that were highly important to the success of the

operations, though not basically of a technical nature. This was an old familiar story to some engineers but to others it was a new experience opening a new field of opportunity. Those who recognized its potentialities and determined to capitalize on it gained a powerful business asset because a man must participate in the business operations of his company if he expects to attain a commanding position.

Possession of technical knowledge does not of itself warrant a high executive rating in any successful company. Unless a man contributes to the business operations of his company he is merely, at the most, like an essential cog in the idler of a train of gears. He neither initiates nor delivers. His service value is measured by the ratio of supply and demand of the men possessing his degree of technical knowledge. Such a man does not cash in on his ability to solve technical problems because of his failure to sell the profitable ideas which he might, and often does, create out of his fund of knowledge.

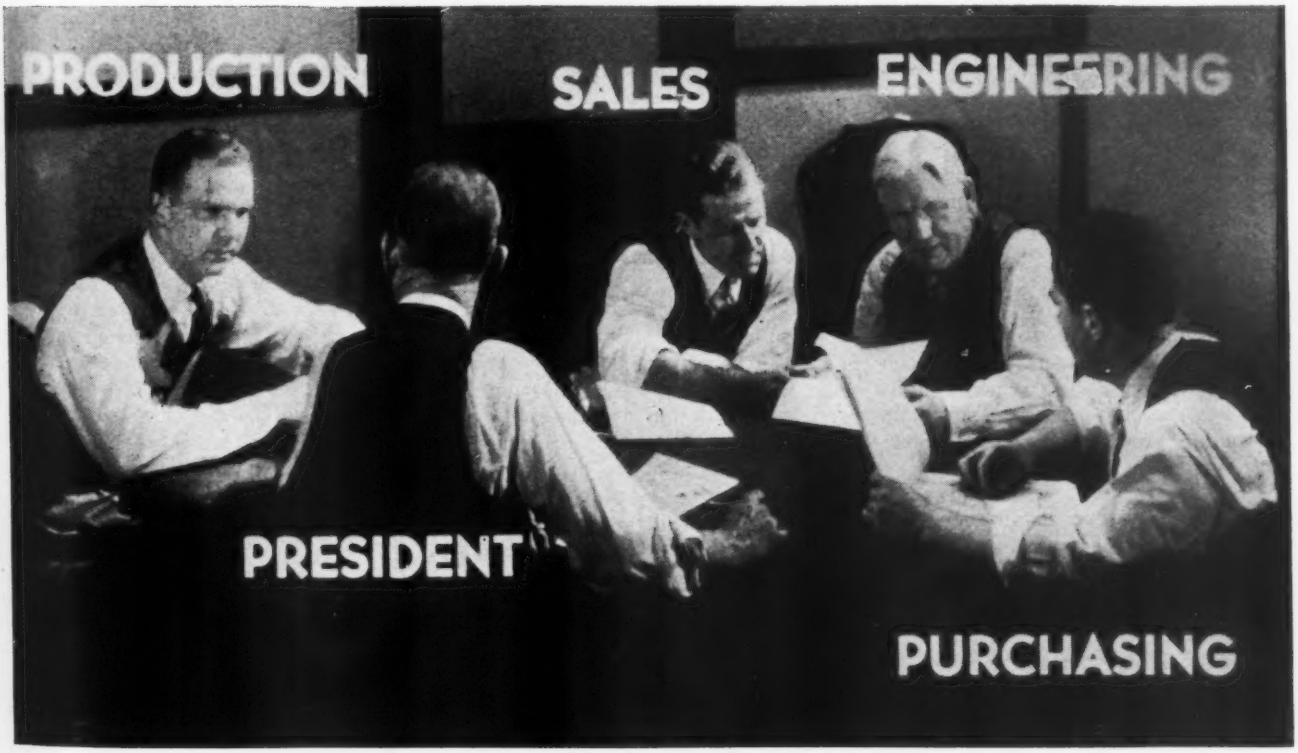
All business is based on salesmanship. Salesmanship is primarily the ability to explain why the idea, service or product offered should be accepted by the prospect. The prospect may be the boss, the board of directors, business associates or a prospective cash customer. Successful salesmanship depends on the ability to be articulate, to express clearly and convincingly the merits of the idea or product offered. The greatest need for salesmanship on the part of an engineer arises from the necessity for him to convince his company executives of the marketability and profit possibilities in the ideas he has to offer.

It is extremely unfortunate that so many of the young engineers upon graduating from college have a totally wrong idea about salesmanship. It is a fact that too many engineers mistakenly pride themselves on not being salesmen. Perhaps past overzealousness in trying to establish the professional aspects of engineering beclouded the hard fact that engineering is a business as well as a profession. Or maybe the professors in engineering colleges put too much emphasis on academic values.

One is reminded of the remark of a steel company executive when asked by a college professor how the engineering courses might be improved. "Teach the boys," he said, "that the only excuse for the existence of a business is to make money and we'll take care of what else they should know." Of course, this business man did not mean it literally but his statement is indicative of the value and need of sound business thinking in engineering. Suffice to say, the engineer who scorns salesmanship not only shows a deplorable ignorance of basic business principles but is also dooming himself to play but a minor role in his professional career.

Before an engineer can attempt to sell an idea to the management, he must have the idea. Not many salable ideas are created by merely sitting at a desk and pondering. Innumerable engineers learned during this war that they had to go out and meet the men using and maintaining the equipment before they could design it most efficiently. Many design improvements had their inception in the mind of the engineer when he saw and discussed at first hand, the service requirements that had to be met. Thus, many designers learned that they cannot serve a customer best until they know what he wants and what is needed in the product to give him what he wants. They also discovered that it requires salesmanship to find out what the customer wants, that is, the engineer must often be articulate to draw out from the customer the information desired. Those engineers who profit from this experience by applying it in their post-war work will gain a plus value from their wartime efforts far in excess of any technical knowledge they may have acquired.

It is not enough that engineers visit the users of the products they design. They should also go out with the salesmen of their company to hear at first hand the arguments for and against the design of their products and the competitors' products. The designer will soon learn the utter worthlessness of some of his pet "design tricks" and the powerful sales appeal of features that had received but scant attention from



Business is based on salesmanship and for that reason all major department executives, including the chief engineer, must be sales conscious.

Articulate presentation of ideas is an important tool for executive engineers. Their active participation in sales conferences demands that they be able to speak in support of their views.

him. In short, he will find out what it is that the customer is willing to pay for. Such sales visits will also prepare the chief engineer to participate intelligently in sales meetings.

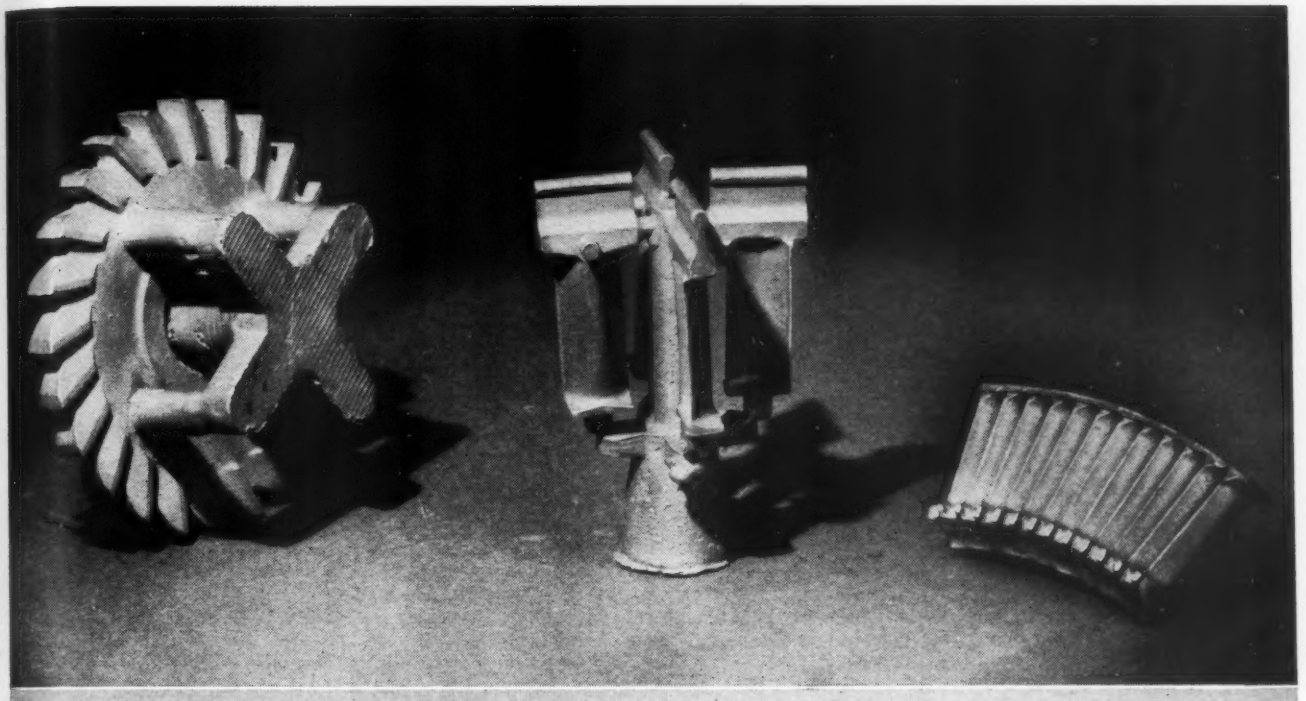
Not only should the executive engineers be required to attend sales conferences, but they should also be required to speak at these meetings. This is extremely important. Sales meetings are open forums at which all the pros and cons of the products' salability are discussed. Engineering executives must be prepared to explain the merits of their designs, discuss the costs of contemplated improvements or the economies in possible design modifications and analyze the sales values of the competing products. Such sales meetings enable the top management to get the engineers' slant. This makes for objectivity in the consideration of any program. If the engineer is of the creative type, he will be in a position to explode traditional methods that are outmoded. If he is articulate, he will succeed in putting his point across, at least to the degree that it has merit. But if the engineer is not a salesman, both he and the company lose if by a poor presentation he fails to get the acceptance of a genuinely profitable idea.

Market research studies can also be made more effective and fruitful if the engineering executives contribute to it. The designer might search out possible design modifications that would give the product greater market possibilities. Undoubtedly after the war the public will be buying things for which at present there is no demand, for the reason that they are not and never have been on the market. Completely new products that have no market history do not lend themselves to market research studies of the conventional type. For such products the chief engineer is in an excellent position to assist in analyzing the market possibilities and to recommend design modifications that will contribute to greater marketability. In every business, its products must survive and it is the engineer who must design them so they can survive. He cannot do this effectively and efficiently if he does not exercise salesmanship. Any man connected with business must be a man of business; he must be interested in all the operations or activities that are related to his particular function.

During this war many engineers have learned and are learning the values in direct customer contact and "selling ideas." Many company managements have been equally impressed by the effectiveness of direct contact between their engineers and the users of their products.

In many of the smaller and medium sized companies, and also in some of the older large companies, the circumstances of war have contributed to the increased importance of the chief engineer's position in the organization. It is up to the engineers concerned to consolidate their gains by entrenching themselves through salesmanship. The first job may have to be to change the ideas of the company management concerning the scope of the duties and responsibilities of the chief engineer. If that is the situation, it will be a test of the chief engineer's salesmanship, his ability to be articulate. If the chief engineer wins his point he is well on the road to being a recognized business man, a position which carries with it respect, prestige and a financial return commensurate with the value of his services to society.

Illustrations other than the headpiece were taken from the C.E.D. slide-sound film "Now is the Time" produced by The Jam Handy Organization.



Precision-castings as they emerge from the mold. A 24-blade milling cutter of tool steel having 3⅞ in. diameter (left), and a cluster of four turbine blades (center) are shown before removal of sprue, gates and risers. Turbine blades are being cast in groups to be fitted together such as the 12-blade section (right), individually and even into whole rings.

Precision-Casting Process Saves Machining Operations

Old technique is revived and improved to turn out small wartime parts of intricate design demanding dimensional tolerances measured in thousandths of an inch. Further research and development may transform this casting method into a specialized field for industrial purposes.

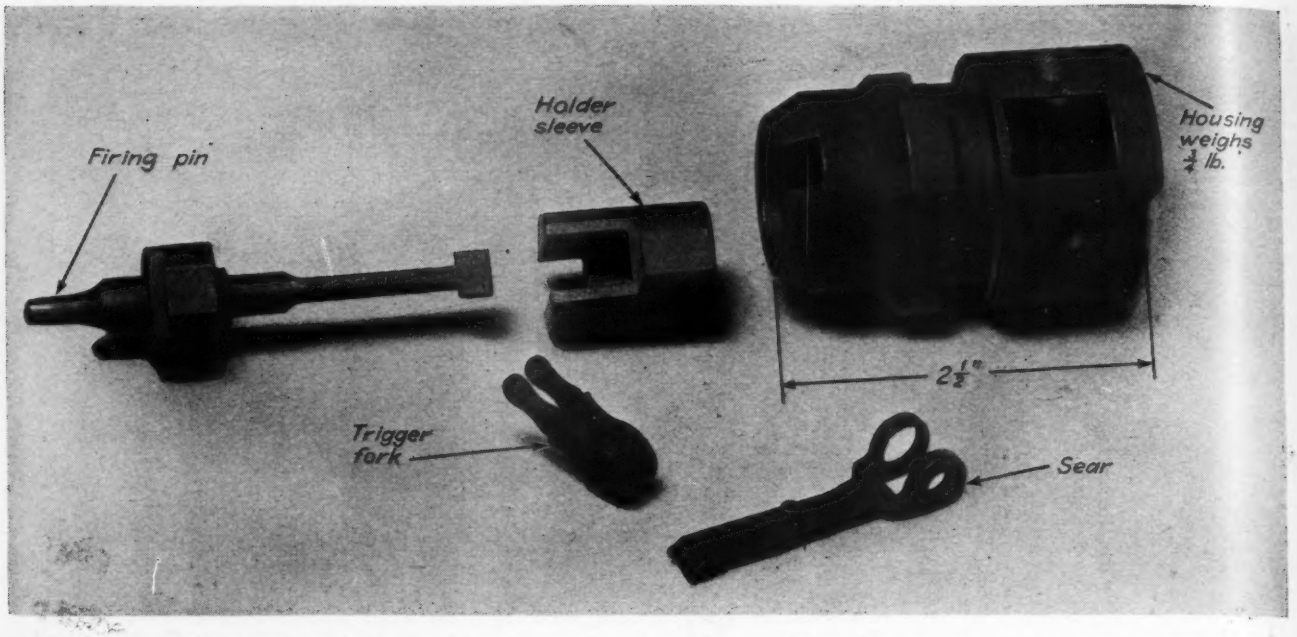
PRECISION CASTING is everything that its name implies. It has received the significant name of "precision casting" because it enables casting to tolerances as low as 0.002 in., depending upon the size of the piece. The process was generally referred to earlier as the "lost wax" or "investment" method of casting.

The technique actually dates back 400 years to the time when Benevenuto Cellini used a special casting process to produce his "Perseus with the Head of Medusa," which stood for many years in a loggia at Florence, Italy. Within recent years the method was further developed for casting jewelry, metal dentures and small surgical parts. This led to its use for simplifying production of many small war parts.

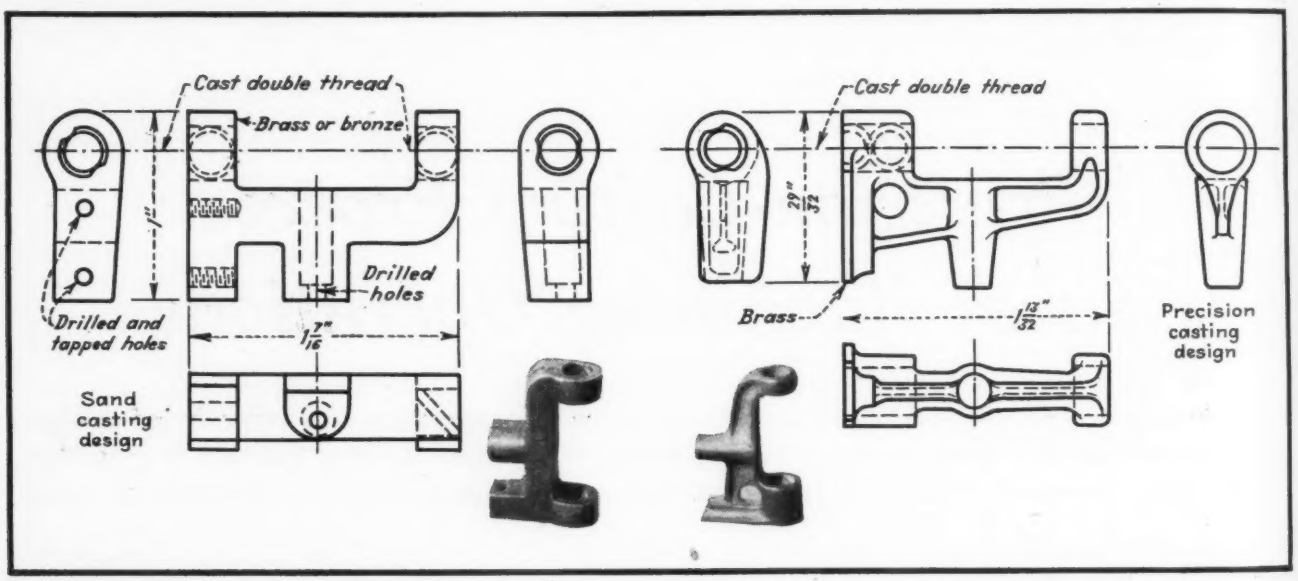
Precision casting is particularly applicable to parts of intricate design that would normally take up much time or unusual machining skill. It permits casting of parts to such accurate dimensions that machining is either eliminated completely or reduced to a minimum. Another important use lies in the fabrication of materials that are unmachinable by cutting tools, or which are extremely difficult to machine, such as the high heat-resisting alloys used for blades, nozzles and other parts of turbo-superchargers and gas turbines. In addition, the method permits fabrication of high-strength materials that cannot be forged, assuring sound metal structure and comparable strength through the application of pressure which is applied centrifugally, by compressed air, or by means of vacuum.

Another advantage of the method, even for metals that can be die-cast, is that it is economically adaptable to the production of small or large quantities, permits greater liberty in design, and the use of stronger materials. Time required for getting production started is short and the ease of changing design, if the first proves inadequate, makes for economy and fast production.

The majority of castings made by this technique have weighed less than one pound. Parts weighing 6 to 8 lb. have been cast, however, and experts believe that size limitations will be increased materially. One firm is developing an intricately shaped aluminum casting that will weigh close to 100 lb. Another has produced a ring-shaped



Main parts of the firing-lock assembly for 75-mm. cannon are precision-cast of WD 6135 chrome vanadium steel by Cuker Process Company. Machine finishing accounts for not more than 10 percent of the former machining time. Dimensional tolerances closer than are practical to cast are produced by grinding. Interior details of the housing include a longitudinal groove between slot and rectangular opening, and a round hole in the lug in back of which the slot passes.



Redesign of this part for precision-casting resulted in less weight, lower cost and reduced production time. Improved metal structure gave the redesigned part the same strength as the original design, which was intended for sand-casting. J. T. Jungersen of Arocast Manufacturing Company, redesigned the part as if it were to be 20 times bigger.

casting of more than a foot in diameter and containing upwards of 100 narrow and well-formed slots.

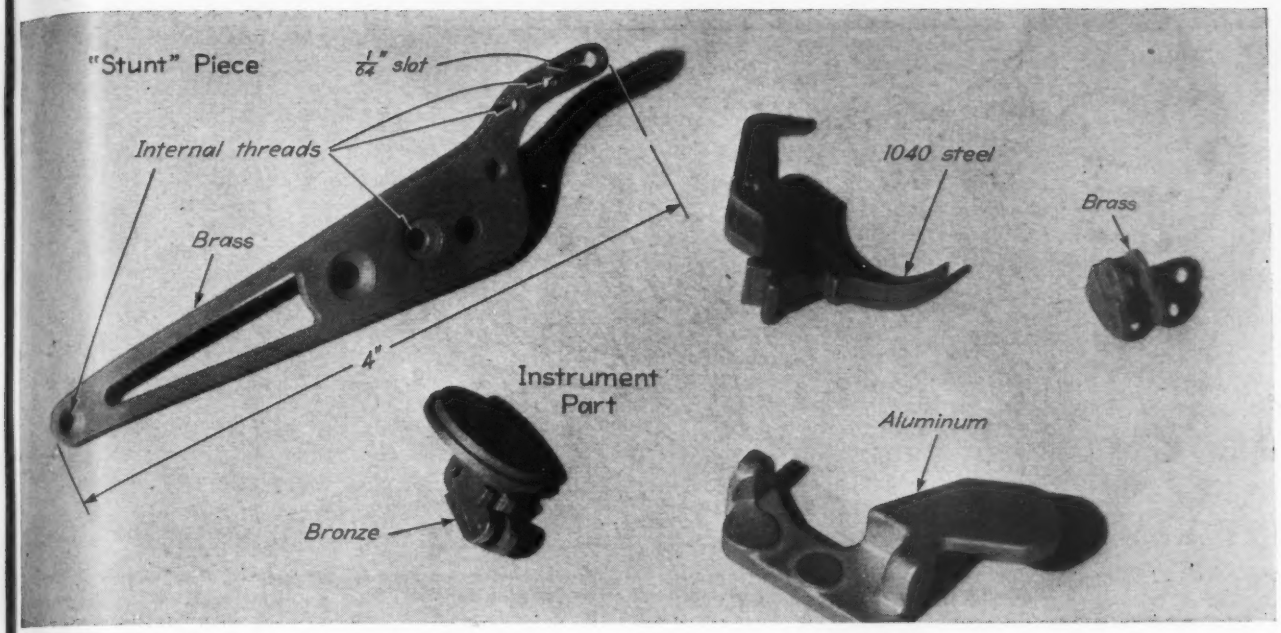
A 16-blade impeeler of 6 in. dia. is another interesting example of precision-casting. It was made of Vitallium, a non-ferrous alloy of cobalt, chromium and molybdenum, by Austenal Laboratories, Incorporated, which for several years has been casting tools and instruments of this alloy for dentists and surgeons, and has cast hundreds of thousands of turbo-supercharger blades.

Precision-Casting Materials

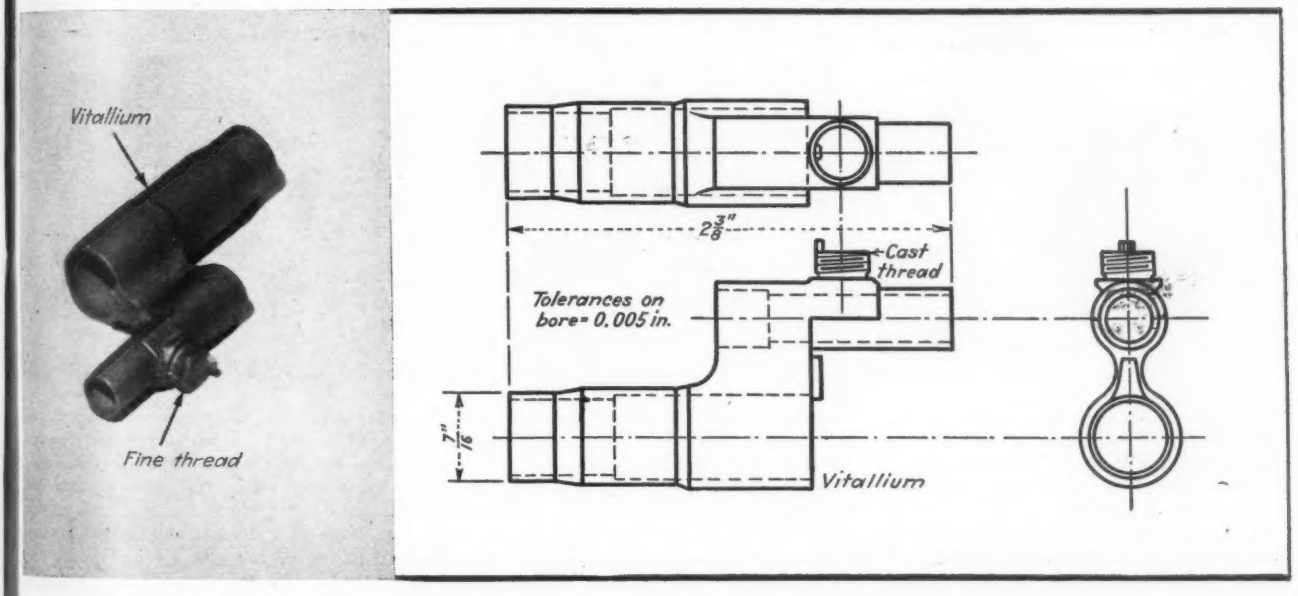
Materials used for precision-castings include brasses and bronzes, various carbon and alloy steels, magnesium, aluminum, monel, and others. Regardless of which of the many castable metals is used, the surfaces of well-made castings are generally smooth and have a frosted appearance. Extremely fine markings on the patterns reproduce on the finished casting.

"There are many variations of the basic casting method," according to a report by L. L. Wyman, research supervisor, and D. Basch, special assistant, War Metallurgy Committee, "but fundamentally the method consists of producing a replica of the desired object in wax, plastic, or some other material, which can be melted and/or vaporized away." These patterns can be made in precisely built metal molds or in molds of rubber, bonded graphite and other materials for less precise work.

The mold into which the molten metal



Skillful mold preparation made possible fine details in a "stunt" part, the largest of five precision-castings shown. Note the narrow slot and internal threads in its small holes, details that are often impracticable for mass production. The wax pattern was made in a rubber mold so that undercut parts could be removed without damaging pattern or mold. The other four castings illustrate practical items of different materials made by Arocast Manufacturing Company.



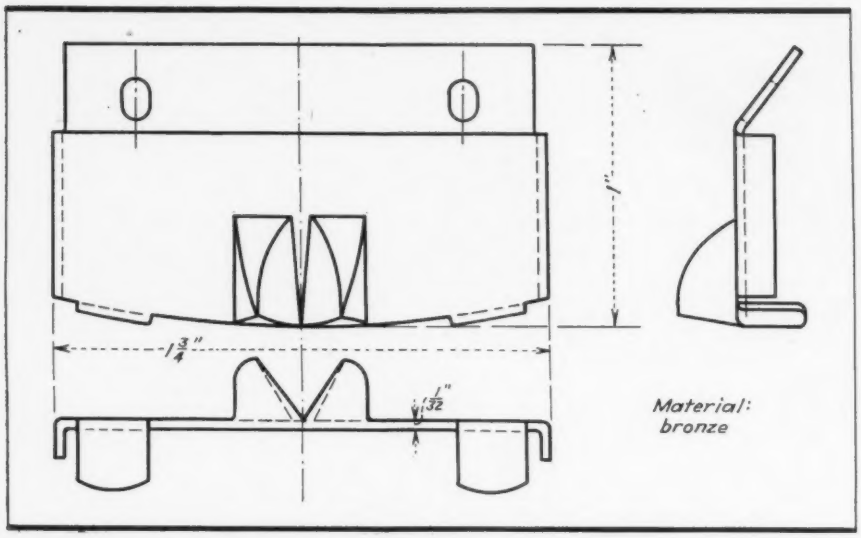
Thin walls of different diameters and fine threads feature this part produced by Austenal Laboratories, Inc. Part is made of stainless steel rather than vitallium, as indicated above. Inside diameters are cast close enough to require only reaming to required tolerances. Threads are chased to remove burr produced at parting line of the wax pattern mold.

is poured is made by inclosing the wax model in a refractory material called the investment. Usually a high-grade silica base material bonded by a silicate or silica-forming compound that sets up quickly is applied in a thin coating on the wax pattern by spraying, dipping or brushing. A lower-grade refractory can then be used to fill the mold container after the part has been permitted to set up. After the entire mold assembly has set, the wax pattern is melted and/or vaporized off, leaving the cavity that is to be filled with molten metal.

The centrifugal method of casting was common in the dental and jewelry trades but methods using pneumatic pressure and vacuum are also in use now to insure proper filling of the mold and to improve metal structure. There are, of course, other details and techniques involved, such as compensation in the wax pattern and investment for dimensional changes, investment material, mold temperatures, gating and others on which the success of the method depends. Problems are further complicated by the fact that each metal must be handled differently.

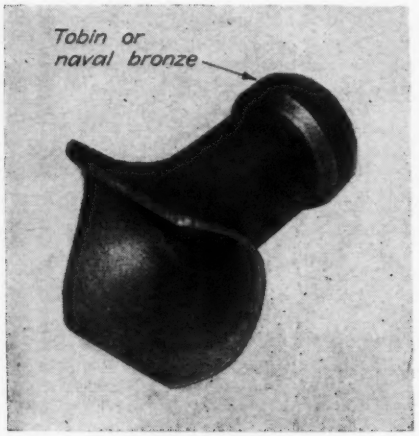
Electric Furnaces Used

The molten charge is usually produced in just sufficient quantity for one mold. In one method the charge is melted by an oxy-acetylene torch on the lip of the mold, then thrown into the mold by centrifugal force when the

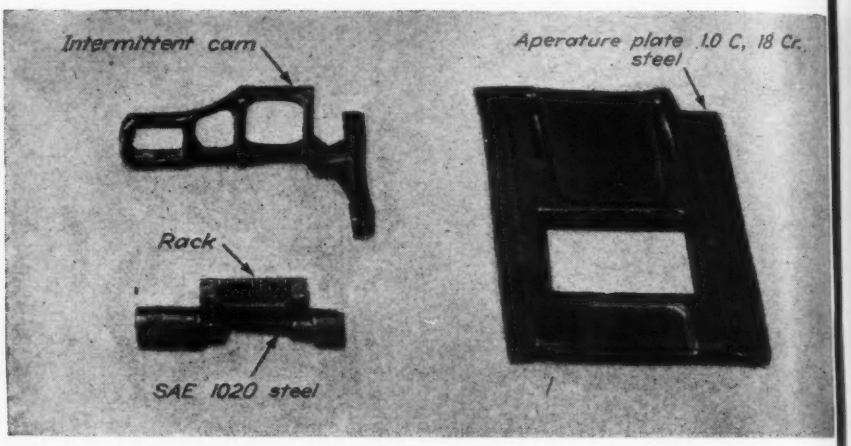


Since projections on this part are easier to cast than to machine, the whole part was precision-cast satisfactorily. Otherwise the part would probably be made of sheet steel, cut and bent to shape with projections soldered, brazed or attached by other means. No finishing operations are required. Courtesy Arocast Manufacturing Company.

Small gears are ideal for precision-casting, which produces accurate tooth contours and saves much machining. Courtesy Arocast Manufacturing Company.



Precision-casting was the third method tried on this flared and flanged tube for aircraft engine electrical connections. A design for die-casting had to be machined inside and was difficult to solder. A design made by automatic screw machines had 30 percent breakage in bending the flared section to shape. Arocast Manufacturing Company method is now used.



Production savings were effected by the Gray Manufacturing Company in resorting to precision-casting for these motion picture camera parts. Aperture plate has an allowance of 0.012 in. on each surface for grinding and polishing after drilling 15 holes. It was formerly milled from bar stock, bent to proper curvature, then ground and polished to final dimensions. Intermittent cam was formerly a forging from which half the metal was machined off to make the shape and dimensions of the present casting. The rack as cast requires only hollow milling of the ends before actual use. The rack formerly was a separate piece forced into a cutout in a forging. As cast appearance is normally better than these samples.

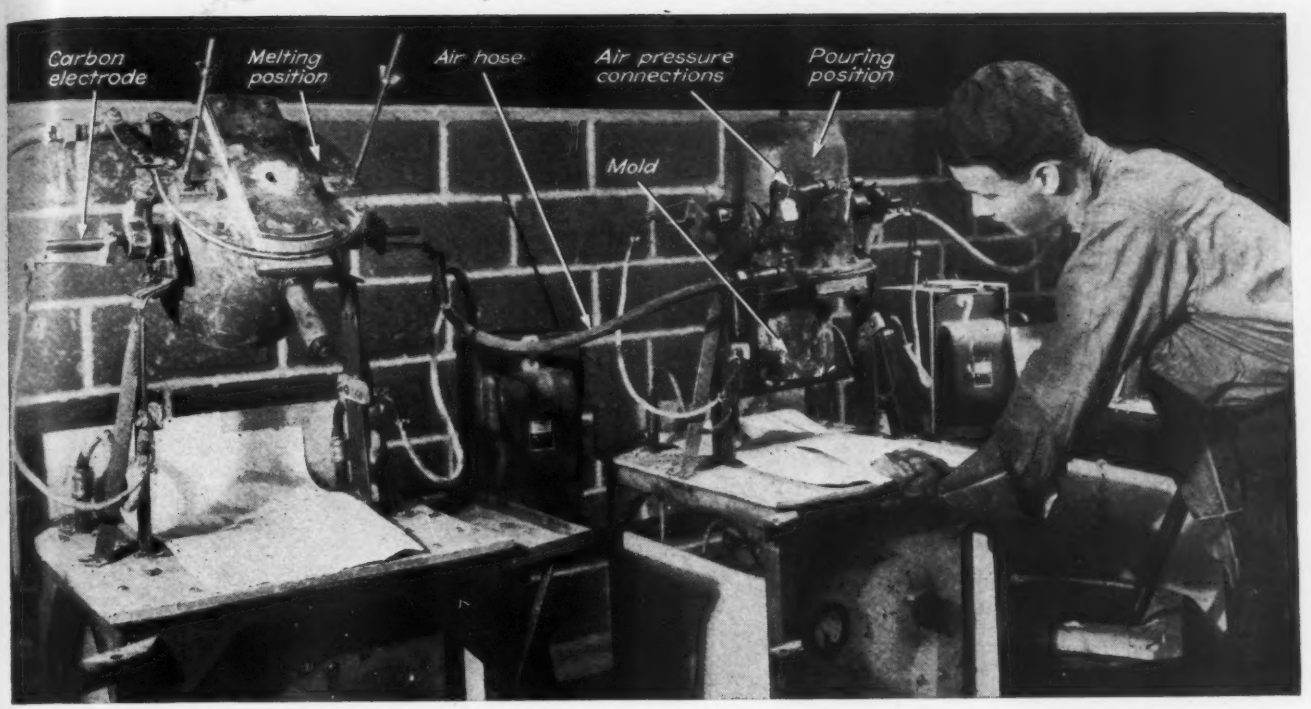
mold swings like a bucket around a vertical axis. Electric furnaces of various types are commonly used for melting the charge.

In another method, a carbon arc furnace melts the charge. The furnace is then inverted to pour the charge into a mold clamped tight to the furnace, and pressure is applied behind the molten metal by air connections to the furnace. The time for melting the charge depends upon the mass of metal and may require no more than a minute in some instances, 15 minutes or more in others.

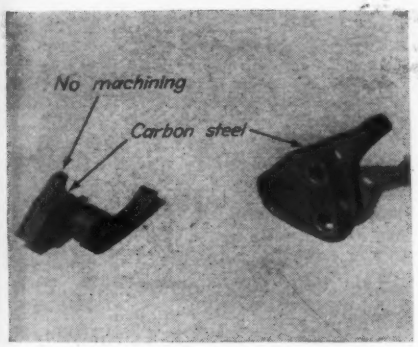
Finished parts are broken out of the mold when cold, and the mold discarded. Removal of sprue, gates and risers is accomplished by either an abrasive wheel or machine-cutting tool, depending upon the hardness of the material in the casting. Parts removed from the mold usually have a certain amount of mold material sticking to their surfaces and in holes and cavities. This excess material is removed easily by sand-blasting, tumbling or similar operations.

A number of improvements and modifications of equipment, materials and technique have been made on the process so that its resemblance to the original Cellini method can be compared to that of the modern Garand rifle to a blunderbuss. These changes have made it possible to cast steels and high-temperature alloys to the close dimensional accuracy, detail, soundness and size indicated in this article. Some of these improvements have been patented by individuals and firms who have given long investigation and development to the process through several years of experience in making precision-castings.

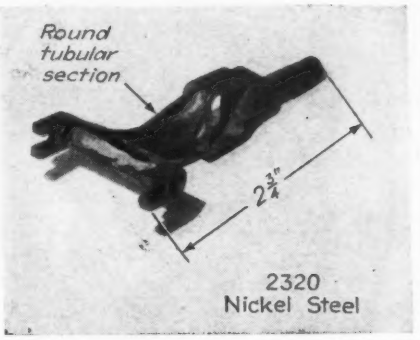
Much is still to be learned about the



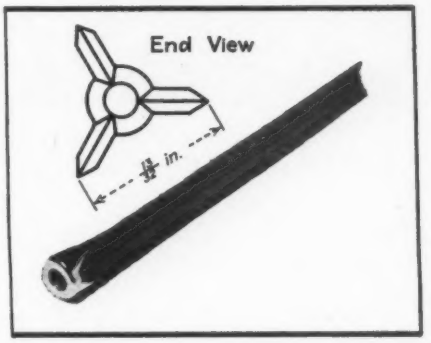
Precision-casting equipment at Austenal Laboratories, Inc., showing positions of carbon arc furnaces during melting of charge and pouring. Pressure is applied by means of air connections to furnace. Connections are open during pouring.



Machining was either eliminated entirely or greatly reduced on these two parts as a result of precision-casting done by the firm of Trifari, Krussman and Fischel. Trigger at left required no machining, and the other part only a minimum. Tolerances of 0.002 in. were required on some dimensions. Physical properties are improved by heat-treatment.



Pull-down arm is one of the 10 high-speed motion picture camera parts made by Cuker Process Company. A grinding operation is used for finishing because of the extreme accuracy required in concentricity and parallelism of holes. Cylindrical stem is ground to dimensions. Material is SAE 2320, one of many materials on which the company has specialized cost.



Fine surface finish and detail are shown in this 4¾ in. triangular spike of Vitallium, used by surgeons for bone repair. A 3/32 in. dia. hole extends for 4½ in. through the 3/16 in. dia. center, and cast internal threads at the round end. Only machining consists of grinding off sprue and polishing round head. Part made by Austenal Laboratories, Incorporated.

general use of the process and about the materials, such as waxes and plastics for patterns, and materials for investments. This will require patient research and development, particularly for the casting of metals and alloys other than the cobalt-base alloys. The present task involves perfecting steps in the process and seeking economical manufacture of larger castings. Precision-casting problems are being studied by firms and individuals and by two government agencies, the Office of Production Research and Development (Dr. Harvey N. Davis, director) of the War Production Board, and the War Metallurgy Committee.

Contrary to prevalent opinion, precision castings are subject to many of the defects inherent in the sand-casting process, such as porosity and blow holes, although they are minimized by application of pressure. On the other hand, they are not subject in the same degree to contamination by the mold material as are sand castings, nor is it necessary to contend, as with sand-castings, with sand-washing defects.

Another source of deficiency in quality of precision castings arises from the necessity, as in other casting methods, or remelting alloys. In this process some of the essential alloying elements might be and often are partially oxidized. The ideal process would be one in which the alloy is produced in a furnace and is fed direct from the furnace into the mold.

Independent Industry Foreseen

It appears likely that the production of precision castings will become an independent industry and that companies will specialize in them, thus making

Red-hot refractory mold for a precision-casting is placed over opening of a carbon arc melting furnace of about 3 lb. capacity at Austenal Laboratories, Inc. Melting temperatures of 2,900 deg. are required for the cobalt base alloy.

them available to manufacturers who do not wish to organize their own producing facilities.

Economies in applying precision-castings depend upon the amount of machining saved or the intricacy of the part, and upon the machinability of the metal used. Precision-casting costs more than ordinary sand-casting and at present costs are affected somewhat by the limited amount of equipment and skill in their production. However, in one instance precision-casting reduced the cost of a part in which both extensive and difficult machining are involved from $25 to $2 per piece.

Design of parts to be precision-cast does not require unusual skill. Many parts for war equipment that had been made by other methods, such as forging, die-castings, and sand-castings, have been changed to precision-castings without redesign. Although this has saved much time, worthwhile improvement is often possible by redesign, applying the same principles of design that are used for larger sand-castings. That is an important rule of design, according to I. G. Jungersen, Arocast Manufacturing Company.

To impress this design rule, Mr. Jungersen recommends that designers consider such parts as if they were 10 to 20 times larger than they actually will be. This point of view assures thinner sections and avoids a tendency toward porous or spongy metal similar to conditions found in sand-casting thick sections of metal in large castings. While pressure, applied by centrifugal force or other means opposes this tendency, present meager experience of many producers new in this field indicates the advisability of using all precautions that will simplify production.

Parts properly made by precision-casting methods often have strength greater than those formerly made by other methods, either because of improved microstructure or change of material. This also is a consideration favoring redesign.

Acknowledgments for providing material for this article are accorded to: T. G. Jungersen, Arocast Manufacturing Company, 10 Aubry St., Summit, N. J.; A. W. Merrick, Austenal Laboratories, Incorporated, 224 W. 39th St., New York; C. C. Cuker, Cuker Process Company, 123 E. 24th St., New York; General Electric Company, Schenectady, N. Y.; H. P. Gray, Gray Manufacturing Company, 107 N. Franklin St., Syracuse, N. Y.; Trifari, Krussman and Fischel, Incorporated, Providence, R. I.; Joseph Robinson, Head Engineer, Industrial Processes and Products, War Production Board.

In addition to the above the following is a partial list of other manufacturers and users of precision-castings: Allis-Chalmers Manufacturing Company, Milwaukee, Wis.; Cleaver-Brooks Company, 5100 N. 33rd St., Milwaukee, Wis.; Chas. J. Fiddleman and Sons, 126 W. 46th St., New York; Ford Motor Company, Detroit; Morris Kaplan and Sons, 21 W. 46th St., New York (see PRODUCT ENGINEERING, Aug. 1943, p. 481); Haynes Stellite Company, Kokomo, Ind.; Lebanon Steel Foundry, Lebanon, Pa.; Jacob Mehrlust, 6 W 46th St., New York; Quality Arms Company, 5823 N. Ravenwood, Chicago; Sperry Gyroscope Company, 40 Flatbush Av. Ext., Brooklyn, N. Y.; Stoody Company, Whittier, Calif.; Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.; H. A. Wilson Company, Chestnut St., Newark, N. J.; Winchester Repeating Arms Company, New Haven, Conn.; J. H. Wood and Sons, 216 E. 45th St., New York.

Dielectric Heating Speeds Curing Of Plastic Laminates

R. W. AUXIER
Section Engineer, Research Laboratories
Westinghouse Electric & Manufacturing Company

Analysis of the advantages of high-frequency heating as compared with conventional methods of curing laminates, including formula for determination of heat developed in material when voltage, frequency and electrical characteristics of the material are known.

DIELECTRIC HEATING of poor conducting materials has been widely used for preheating plastic materials before molding, curing plywood, drying leather and many other applications. Suggested uses of high-frequency dielectric heating include drying of various materials such as wood and ceramic bodies. Heating a material by high frequency is usually expensive in the unit cost of heat, but the over-all result may be much more economical. For example, with a 3 in. laminate the small additional cost of heat is negligible as compared to the three hours of press time normally required. Production would be nearly doubled, overcoming the slight extra cost for power.

This method has accomplished results that could not be attained by other means. For example, thick sections of hot resin-bonded plywood can be turned out by dielectric heating. Surface heating is impracticable because the wood surface would deteriorate from exposure to elevated temperatures for long periods before the resin in the center is cured. Some work has been done on high-frequency heating of solutions. Thus the method may in time be used for chemical processing. For example, a corrosive material might be heated by high frequency inside a ceramic vessel. Heat need not pass through the walls, and resulting high thermal stresses would be avoided.

More exact knowledge concerning high-frequency heating of laminated plastic material is perhaps the most important factor in furthering the adoption of this new technique. For example, recent research investigations show that about 2 kw. capacity per lb. of material, or 0.033 kw. hr. is required to reach curing temperature in one minute. Based on 50 percent efficiency, input to the oscillator is but 0.06 to 0.07 kw. hr. per lb. of laminate. Time for uniform curing, effect of hot and cold platens, and the relation of molding pressure to density are other findings of recent research that are helpful in evaluating dielectric heating as a process.

Heat developed is proportional to the frequency, the loss factor and to the square of the voltage. Although raising the voltage would appear to be the easiest way of increasing the temperature, high voltages are a source of trouble. Flashover at the edges, internal corona, dielectric breakdown are all caused by high voltage. Raising the frequency is the other method of increasing the heat, but equipment problems limit the upper range. In general, dielectric heating is

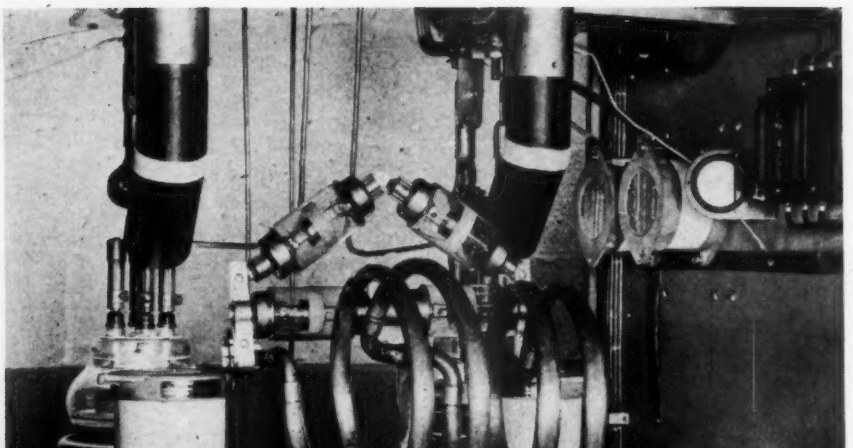
Table I—Percent Moisture Absorption and Acetone Extraction at Various Surfaces of Laminated Material Cured by Dielectric Heating

	Percentage for 24 Hr. Moisture Absorption	Percentage of Acetone Extraction	Hardness Rockwell M
Surface No. 1	1.73	4.3	70.2
Position No. 2	1.58	2.5	
Position No. 3	2.05	1.7	
Position No. 4	1.84	1.8	
Position No. 5	1.94		
Position No. 6	1.81		
Surface No. 7	1.54		

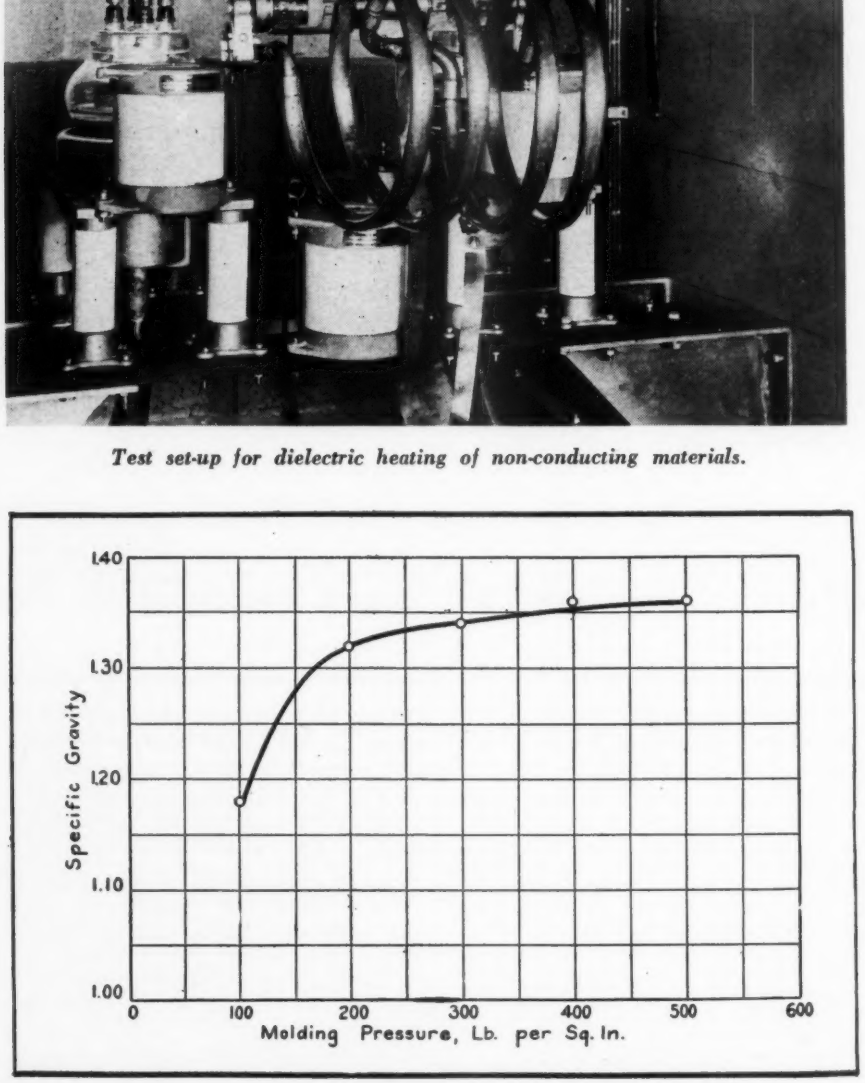
Table II—Effect of Time on Comparative Hardness Moisture Absorption, Acetone Extraction

Sample	Rockwell M Hardness		Percentage for 24 Hr. Moisture Absorption		Percentage for 7-Day Moisture Absorption		Percentage of Acetone Extraction
	Surface	Center	Surface	Center	Surface	Center	Surface — Center
Regular Production Micarta*	94.6	82.3	1.56	1.67	3.64	3.65	7.1
No. 19 H.F. 20 min	98.4	88.0	1.44	1.60	3.58	3.66	2.7
No. 19 H.F. 10 min	95.0	86.3	1.41	1.48	3.50	3.56	10.3**
No. 21 H.F. 5 min	94.3	90.0	1.89	1.57	4.37	3.70	6.0
No. 16 H.F. 1 min	90.9	78.2	2.56	2.08	6.23	4.83	13.2

* Regular production pressure is 1,000 lb. per sq. in. for min.
** This value out of line.



Test set-up for dielectric heating of non-conducting materials.



Variation of specific gravity with increase in molding pressures.

most efficient when operated at the highest practical voltage and frequency suitable for a given material and size of work.

The curing of thermosetting resins used in making laminates is generally done by heating for a certain time at a given temperature. Usually, the higher the temperature the shorter the time. Also it is generally accepted that it is better to cure any given resin above a definite temperature to obtain optimum properties. For example, urea resins should be cured above 120 deg. C. and phenolics above 140 deg. C., if best properties are to be developed. The sheet, placed in a hydraulic press between heated platens, is subjected to a specific temperature, say 160 deg. C. in the case of phenolics, and held at this temperature for several minutes.

For thin pieces of material, this procedure is quite acceptable since the center of the laminate reaches approximately the temperature of the platens in a short time. Platen temperatures do not have to be much greater than the temperature desired at the center of the piece to cause the heat to flow rapidly to the center.

When the thickness is known and the material is heated uniformly from both sides, the approximate time required for the center of a piece of material to reach 90 percent of the platen temperature is:

$$t = \frac{8.15\ \sigma\ h_s\ l^2}{K_e}$$

where

l = thickness of piece in inches
h_s = specific heat
σ = density in lb. per cu. in.
K_e = thermal conductivity in watts per sq. in. per C. deg. per in.
t = time in minutes

By this equation, time for various thicknesses of a paper-base laminate is as follows:

1/4 in. thick	1 3/4	min.
1/2 in. thick	7	min.
1 in. thick	28	min.
2 in. thick	112	min.
4 in. thick	448	min. or nearly 7½ hr.

Total time of cycle is the sum of the calculated time to reach 90 percent platen temperature plus time required to cure the resin and time to cool the material for removal. Thus molding cycles for heavy or thick laminates become quite long. With dielectric heating, the time required to bring the material up to molding temperature, the cure cycle is considerably reduced.

To determine the effect of time of application and molding pressure variation, phenolic-resin fabric base laminate was molded under controlled laboratory conditions. During preliminary tests the heat conducted away from the surface of the laminate by the metal platen was so great that the surface was under-cured. To prevent this the platens were heated with steam to the approximate molding temperature and used as electrodes. The temperature of the material was raised to curing values, from 160 deg. C. to 180 deg. C., depending on the kind of material used. The piece was then held at this temperature by reducing power supplied by the oscillator. After the resin had sufficient cure the press was cooled by circulating water through the platens.

The first tests were made to determine the length of time required to cure the resin under these conditions. Laminated plastic plates ½ in. thick were molded at 180 deg. C. and 500 lb. per sq. in. pressure using different time cycles. Two to three min. were required to raise the material to curing temperature, at which it was held from 1 to 1½ min. and then cooled. Total time for these cycles from the placing of the material into the press until it was removed was 20 to 35 min. As a measure of cure moisture absorption and acetone-extraction values were run on samples taken

from the surface and from the center of each piece.

To investigate the relative curing schedule for heavy sections, a laminated piece 3 in. thick was molded at 500 lb. per sq.in. pressure for 2.5 min. at the maximum temperature. The temperature was raised at the center to 180 deg. C. in 25 min. It was held at this temperature for 2.5 min. and then cooled for 3 hr. Cycle totaled approximately 3½ hr. The conventional cycle for this size laminate is 3¼ hr. for heating up to curing temperature and curing, plus 3 hr. for cooling, or 6¼ hr. total.

Moisture absorption and acetone-extraction samples were taken at seven places throughout the block. By properly heating the platens with steam, uniform cures throughout the thickness of plates were obtained.

In 1864 Siemans published a note on the heating of the glass walls of a Leyden jar during charging and discharging. Since that time a great deal of study has been devoted to the electrical losses that appear as heat in the insulation of alternating current circuits. Some methods of measuring these losses involve determining the energy lost by the heat developed in the materials. These losses are in part a function of the material itself and of the frequency. They are of importance in insulation used on 60 cycle circuits or the most common power circuits. They are extremely important on radio frequency where the frequencies are in the millions of cycles per second.

The heat developed in a material is

$$\text{watts loss} = (C_o) \times E^2 \times 2\pi f \times K \times \tan \delta$$

When using parallel plates as electrodes:

$C_o = 0.224 \times A/\text{d} \times 10^{-12}$ when dimensions are in inches

Then:

$$\text{watts loss/cu. in} = 0.224 \times 10^{-12} \times 2\pi f \times K \times \tan \delta \times \left(\frac{E^2}{d}\right)$$

where

E = total voltage across the sample (r.m.s. volts)
A = area
f = frequency in cycles per second
K = dielectric constant
$\tan \delta$ = tan of the loss angle
d = thickness of sample

The factors K and $\tan \delta$ are properties of the material and are dependent on temperature and frequency.

Combining all constants for a fixed electrode system:

$$\text{watts loss per cu. in.} = (1.41 \times 10^{-12}) \times \left(\frac{E^2}{d}\right) \times f \times K \times \tan \delta$$

The properties of a material that make this method applicable are the factors K and $\tan \delta$. In electrical insulation these two factors are usually combined into one so that

$\epsilon'' = K \times \tan \delta$ = loss factor

This factor for polystyrene is so low, 0.005 or less, that little heat is developed. In the case of plastic laminates made with phenolic resins this value may be 0.3 to 0.4. For materials with loss factors of 0.1 or greater the heat developed is sufficient at high frequencies to give appreciable heating.

REFERENCES

Ueber Erwarmung der Glaswand der Leydener Flasches durch die Ladung. Von Dr. W. Siemans, Aus d. Monatsberichte d. Berlin Akad. (1864) Oct., *Jour. der Physik. Annalen der Physik. Poggendorff* Vol. 125 (1865), pp. 137

The Calorimetric Determination of Energy Dissipated in Condensers, E. B. Rosa and A. W. Smith, *Phil Mag.* Vol. 5 No. 48, pp. 222-236 (1899)

Heatronic Molding, Meharg, *Modern Plastics*, March, 1943

Heatronic Molding, Mehard, *Bakelite Review*, Vol. 15, No. 1, April, 1943

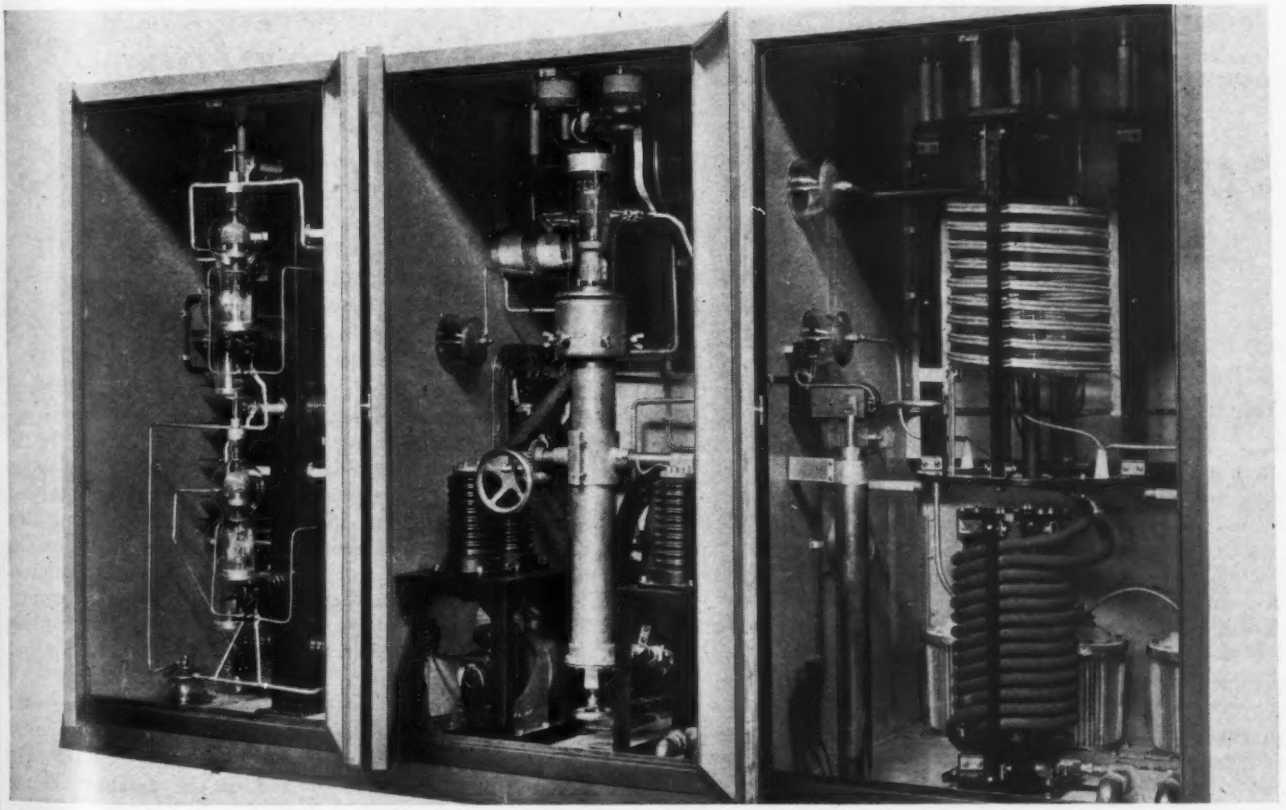
Tubes at Work. FR Speeds Plywood Bonding, *Electronics*, Nov. 1942, pp. 79. U.S.P. No. 2,212,522

German Patent 677,522

British Patent 310,925, 1928

Heating of Simple Solutions and Emulsions Exposed to High Frequency High Potential Electrostatic Fields, Marshall, *Journal of Gen. Physiol.* 13, pp. 637-646 (1930).

Electrostatic High-Frequency Heat Makes Possible New Designs PRODUCT ENGINEERING, Jan. 1943 pp. 40-44.



Three-cubicle unit containing rectifier, oscillator tube and oscillating circuit.

Scale model proved advantageous in the development of a mobile power plant. The model shown enabled engineers to obtain the relative location of units and thus achieve a compact and efficient design. It likewise permitted three-dimensional visualization. The mobile power plant, an innovation, was developed jointly by engineers of the General Electric Company and the Greenville Car Company.

Shortcuts for Trial Samples Speed Development of New Products

JOHN YOUNGER

Chairman, Department of Industrial Engineering, Ohio State University

SOON manufacturers all over the country will be in a more or less mad scramble to beat competitors in the race to be the first to make their post-war products available to buyers. This healthy situation will speed greatly the return to full peacetime production and thereby shorten the period of unemployment.

In the development of a new product, the greatest time-consuming factor is the manufacture of the trial sample, the subsequent testing and the numerous changes dictated by the performance and analysis of the sample. To put the new product into full production before it has been subjected to a searching investigation with reference to both its performance and the methods of its manufacture is invariably expensive and invites disaster. Obviously, the manufacture of a test model is usually essential. However, by painstaking planning it is relatively easy to reduce greatly the time involved. Often by virtue of building a test model the time required to get into full production is considerably shortened. Not only does the test model reveal functional shortcomings but it also gives the production men an opportunity to study the actual product and devise manufacturing shortcuts and economies in assembly.

The old adage, "One thing at a time," does not apply in modern manufacturing operations. To the contrary, amazing progress is made by doing several things simultaneously, that is, by applying the Law of Simulation. If the second step is taken just as soon as the progress of the first step permits, and in a like manner each succeeding step is begun at the earliest moment possible, a great number of steps can progress simultaneously. The total time required for the complete job is then not the sum of the time required for each step, but only a fraction thereof.

This principle can be applied with great effect in the development of new products. For example, usually the frame or bed of the machine is the first element designed. It is necessary to wait until every hole and bracket

has been located on the frame before sending the drawings to the pattern shop. Just as soon as the over-all shape and principal dimensions have been established, photostats of the pencil layout should be sent to the pattern shop. By the time the patterns have been made the design will have developed to the point where the engineer feels certain of all the important dimensions. Last minute necessary changes can be made in the patterns and they are then sent to the foundry without further delay.

Meanwhile, other major elements of the machine are being developed on the drawing board. For example, a part may be designed to be machined out of a heavy hammer-forging. As soon as the over-all dimensions have been established, the forging should be ordered. If a part is to be made as a die-forging, the block of steel for making the dies can be ordered as soon as the over-all dimensions of the piece can be judged. While the diemaker is waiting for the steel, the designer progresses with his job to the point where all nominal dimensions are established. Without waiting until tolerances have been established, the designer sends a copy of his drawings to the die shop and the diemaker begins to rout out the die-block to an approximate shape. Upon receiving the finished blueprint, the diemaker completes the job to the final accurate dimensions. In the meantime the drop-forger has been notified of the size of billets required and he is ready to make the finished drop-forgings as soon as the dies are completed.

Obviously this system cannot work most effectively if numerous formalities must be observed. The system can only be successful if "red tape" such as requisitions, order forms, checks, approvals and similar time-consuming motions are minimized or eliminated. Direct action in the building of first test models pays large dividends. Free hand but clear pencil sketches, photostats of pencil drawings, telephoned or telegraphed orders, close personal contact and cooperation between department heads all contribute immeasurably to speeding completion of the test model.

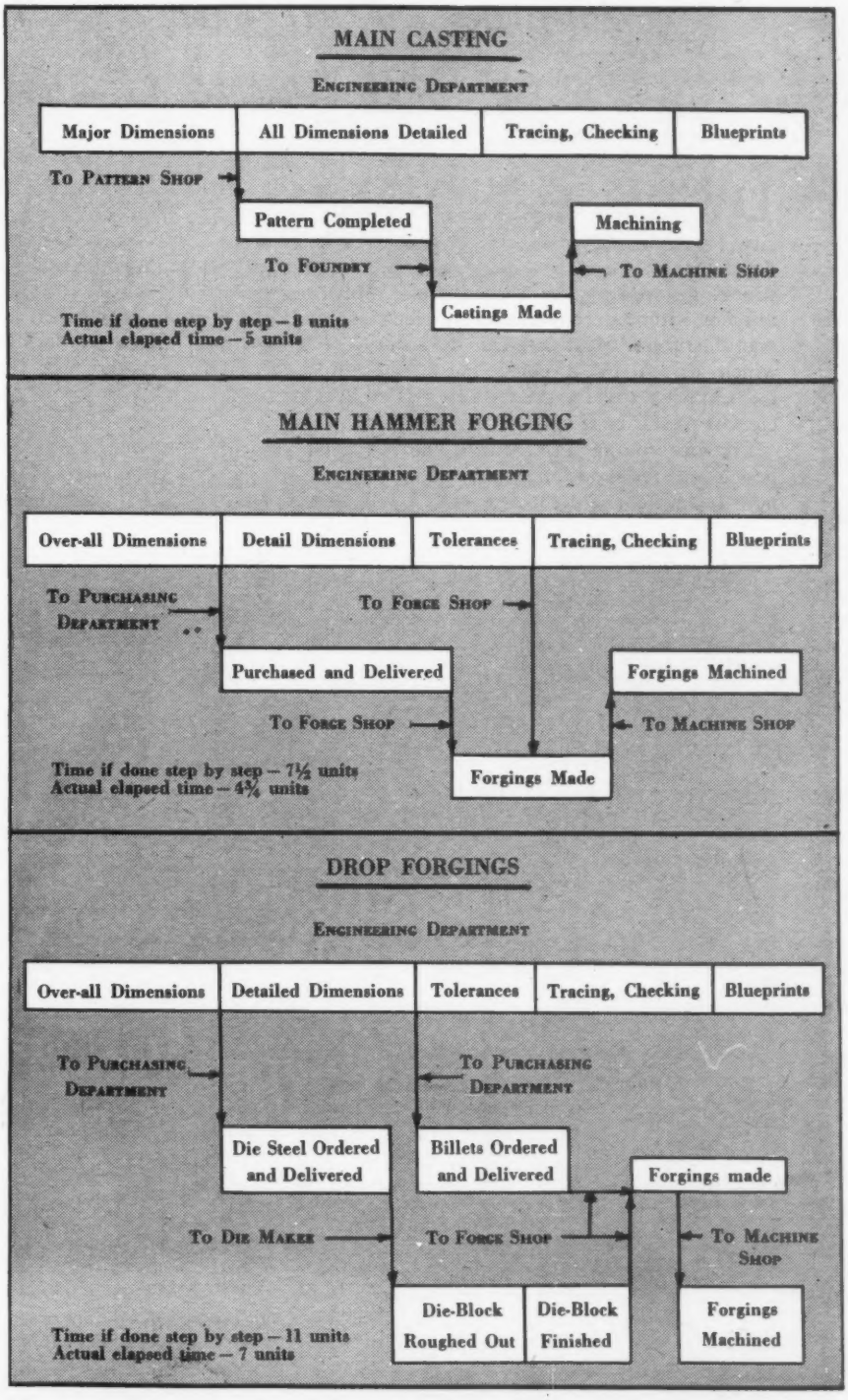
Just as soon as the part is finished, all dimensions are checked and proved by assembly to the associated parts, the toolmaker can start on the jigs, fixtures and gages for the production department. Usually it is not wise to begin tooling until the test model has been "shaken down" to its final dimensions. Few special tools will be needed in building the model, so there is little or nothing to be gained by tooling for the first model. Furthermore, changes made in the test model might make it necessary to change the tooling.

The accompanying chart shows an example of the application of the Law of Simulation to the development of a hypothetical product. Admittedly, there is always the danger of "haste making waste" but reasonable care will serve to avoid most major mistakes.

By the use of fusion-welding, extensive changes can be made in the various parts as the trial model develops. The cutting torch is equally effective in improving a design. Small holes can be tapped and plugged if they are found unnecessary. Occasionally it may be found necessary to remake a part. But the cost of such changes is invariably offset by savings in design costs.

With the opportunity of seeing finished parts, such as housings, shafts and gears, as they develop, designers can work faster and with more assurance.

The greatest advantage in speeding the design to its final completion, however, lies in the earlier date at which the product gets into the shop for marketing. An empty shop is a loss to men and management, and there is no money coming into the company's treasury until the product is on sale.



This chart details swift-moving steps which can be adapted to the development of trial samples. Simultaneous procedures help to avoid tie-ups.

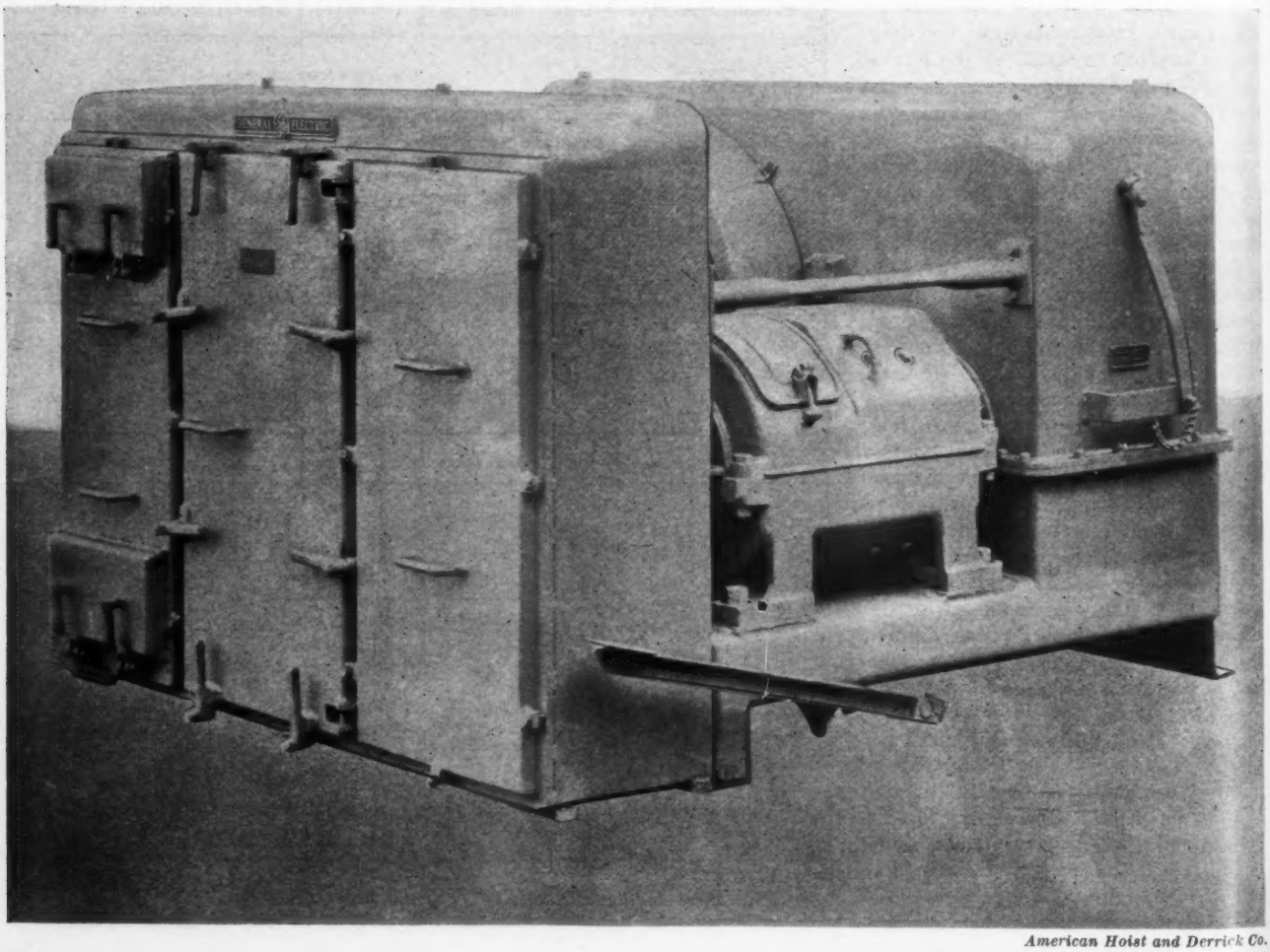
WARTIME DESIGNS

Compact Unit Cargo Winch Bolted to Open Deck of Ship

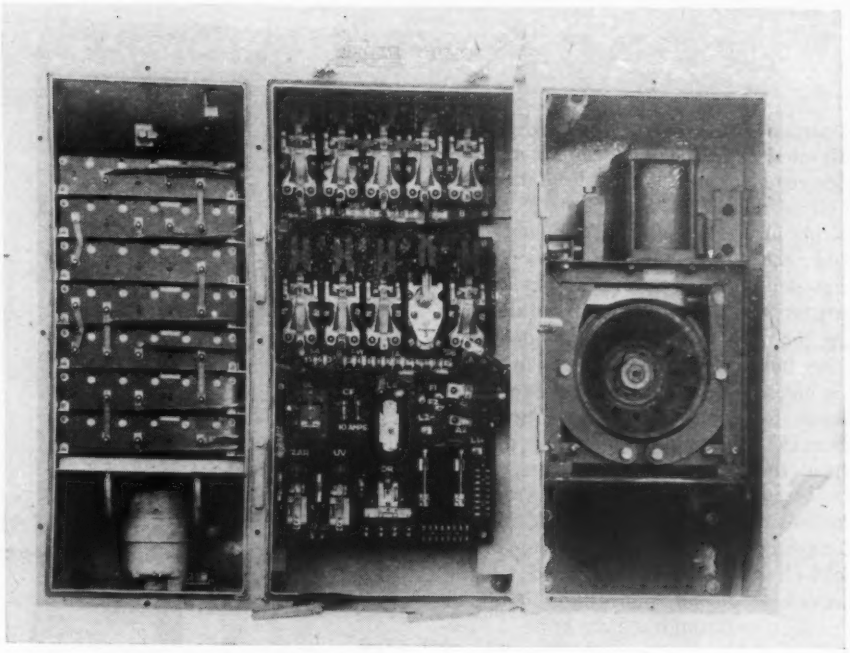
DEMANDS for reduction in the size of deck houses to allow more cargo space plus the wartime necessity for reducing man-hours for installation led to development of a sturdy, compact design of unit cargo winch, fostered by the United States Maritime Commission with the cooperation of electrical and winch manufacturers. Most large modern cargo ships use a winch driven by a compound-wound direct-current motor having speed and torque controlled by a magnetic control panel, resistors, and a master switch.

Previous to the new design, the magnetic control panels and resistors were mounted in deck houses. The new unit winch, as described by C. L. Eiglebach of the Federal and Marine Engineering Division of General Electric, incorporates control panel, resistors, and brake in one three-section compartment which is secured to the winch base so that the entire assembly can be handled as a unit. It is shipped as one unit to the shipbuilder and it is merely necessary for him to bolt it in place on deck and connect up the necessary power cables.

Any one of five speeds for hoisting or lowering the cargo is obtained by moving the handle of the master switch. This switch is mounted on the open deck and is of waterproof construction. It is fitted with cam-operated double-break silver contacts.

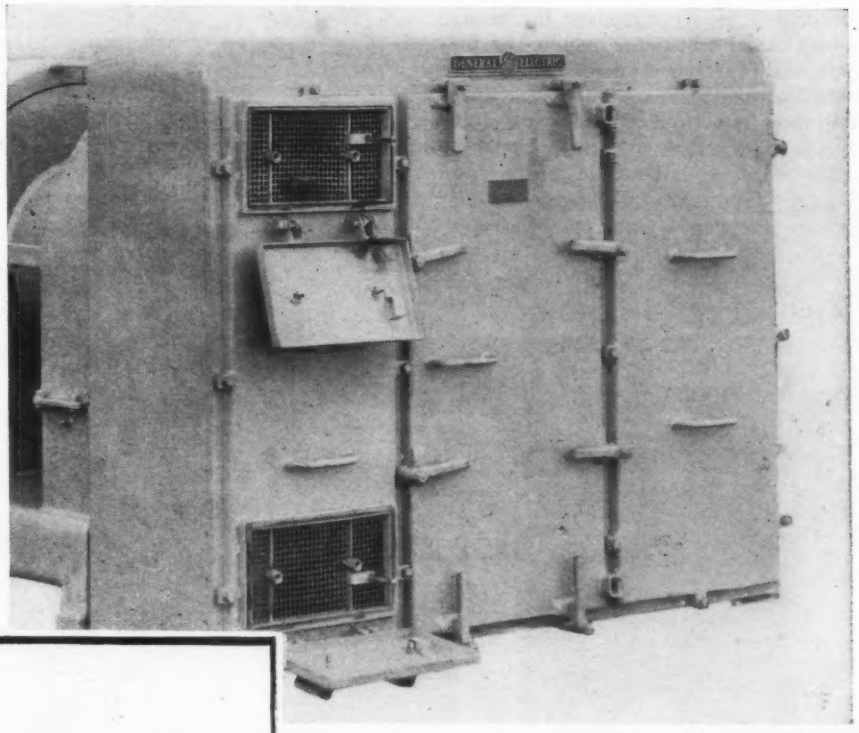


American Hoist and Derrick Co.



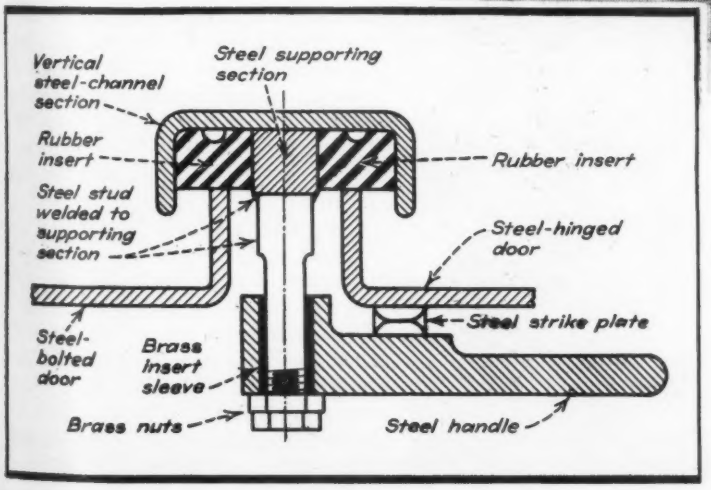
Electrical equipment in place and doors removed, as designed and built by the General Electric Company. Compartment is in three sections, housed in a welded casing of $\frac{3}{16}$ in. steel. Design had to be waterproof and have necessary rigidity and strength to withstand rough usage encountered during shipment and installation. Welded construction made the case waterproof except at the doors where a construction similar to that shown below is used.

Bolts on the two outer doors and the handles on the center door force the steel door edges into rubber inserts. Thus the compartment sections are waterproof but doors are removable at any time for inspection, adjustment, and maintenance. An automatic drain valve is located in the bottom of each section to draw off any water which might collect at this point.



American Hoist and Derrick Co.

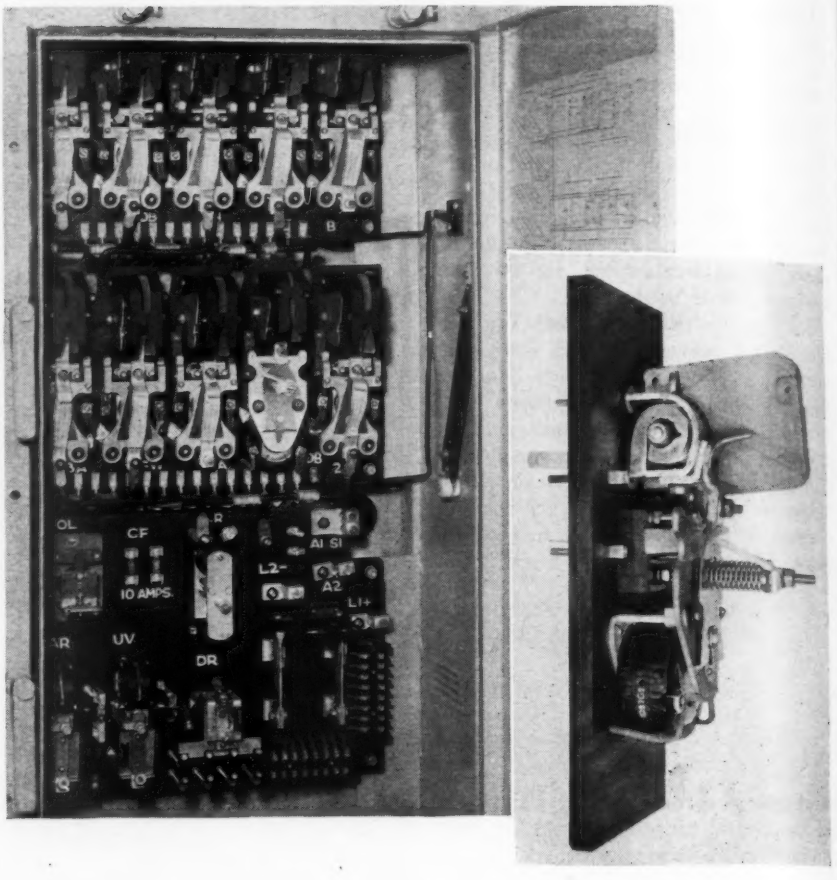
Resistor section at the left-hand side has two small hinged doors at the top and bottom which are swung open when the winch is in use. Two screw handles secure each of these small doors in place while the winch is inoperative. Both doors are electrically interlocked with the control so that they must be open before the winch motor can run. With doors open, air is pulled in at the bottom and pushed out at the top. Air is circulated through the resistor units by a small motor and fan located at the bottom. The resistor units are assembled in readily removable boxes for maintaining or replacing. Horizontal guides are secured to the sides of the resistor section to allow the resistor boxes to slide out and replace easily. Simple strap electrical connections on the front are also designed for this purpose. Box frames have solid back, front, and sides for more efficient air flow over the resistor units, since considerable heat must be removed to prevent overheating of the steel inclosure and resistor units. Resistor units are likewise easily removed from the boxes.

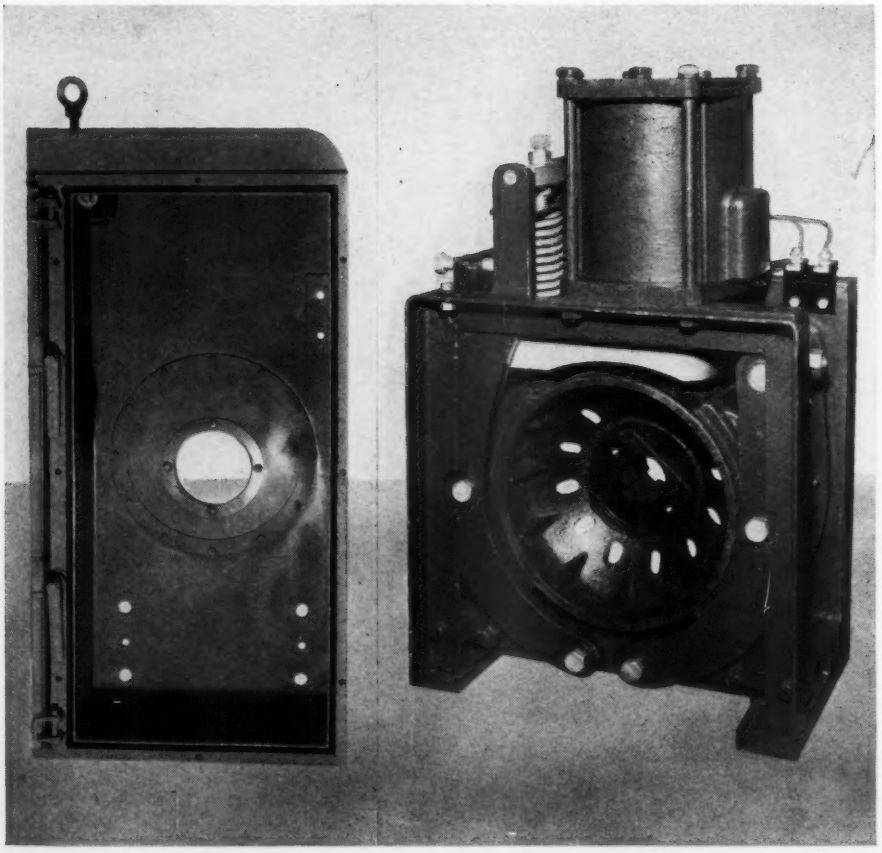


(*continued on next page*)

Compact Winch Control (continued)

Control Section. New lightweight Merchant Marine type contactors were designed to meet space limitations. A unique feature is the synthetic rubber pivots for the armatures. The contactors and the other control devices are mounted on three separate bases so that any one can be removed without disturbing the other two. To remove one of the three bases, it is only necessary to loosen the electrical connections at the terminal board for each base, remove two nuts from the upper supporting studs and remove the two lower supporting bolts. Leads come into this section through a conduit directly from the motor and are connected into the circuit by means of solderless connectors provided on the lower base. Power connections come into this section through a plate bolted to the bottom of the compartment. The plate is removable so that proper size holes can be drilled to accommodate the ship's power cable. A heater is mounted on the side of this section to minimize condensation of moisture on the devices when the winch is not operating.

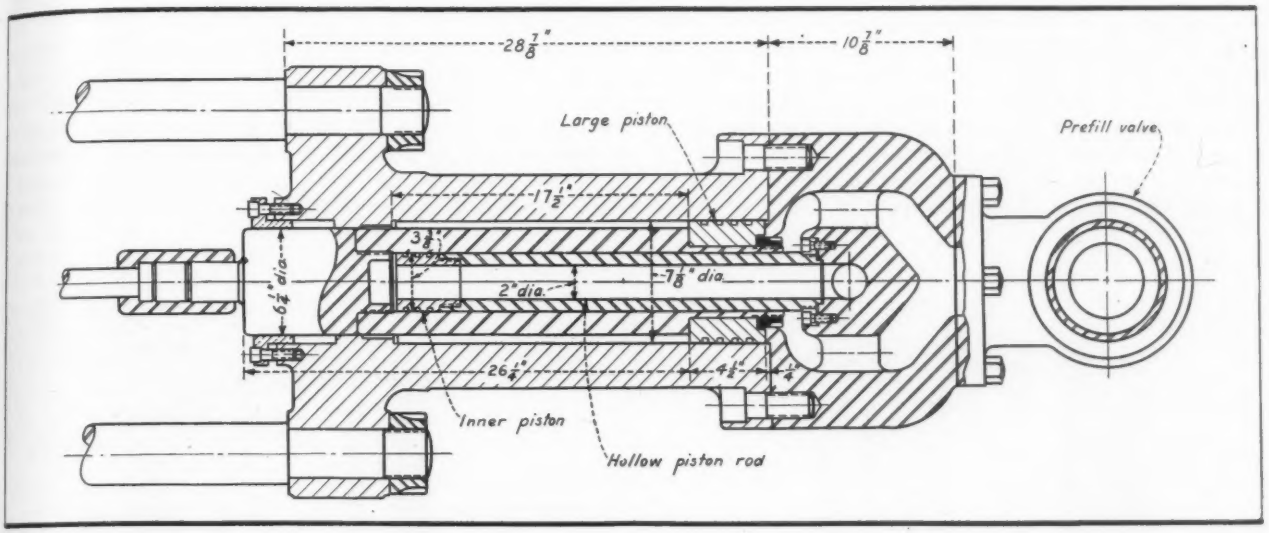




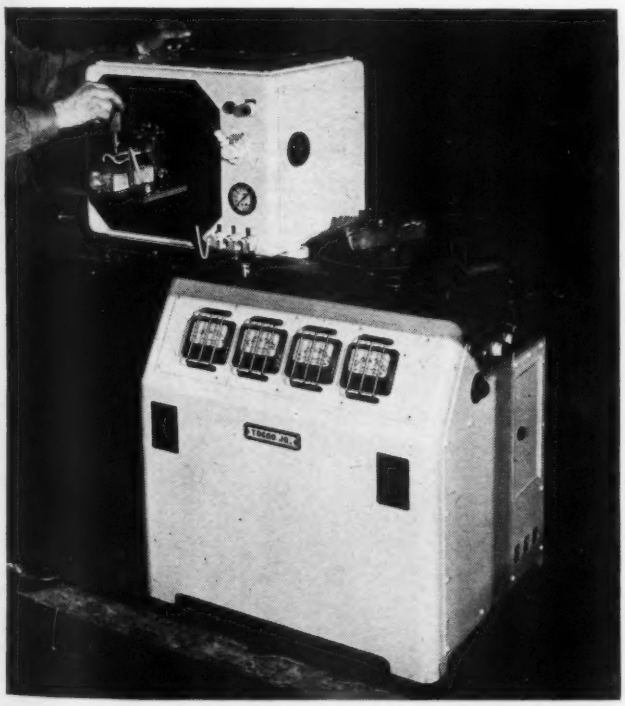
Brake Section. The commutator end flange of the motor is bolted to the back of this section as the shaft extension must extend into the compartment to allow mounting of the brake wheel. Motor flange is bolted to a ⅛ in. steel diaphragm by four bolts. This diaphragm in turn is bolted to the compartment by 12 bolts. Rubber gaskets are used to make these joints watertight. This construction is necessary so that the motor armature can be removed without disassembling the winch. The top half of the motor frame can be swung out of the way and by removing the 4 flange bolts and 12 diaphragm bolts, the motor armature can be taken out.

At right is shown new design of vertical acting shunt-wound brake. Compact design was necessary to meet the limited space requirements. Adjustments for torque setting and shoe clearance have to be easily accessible. The coil must be readily removable. This allows the operator to make repairs or changes in adjustment with a minimum of effort.

Pre-Fill Injection Cylinder Used on Die-Casting Machines



Advantages over ordinary injection methods used on die-casting machines were obtained by Lester Engineering Company engineers by use of the well-known hydraulic fast-traverse principles used on hydraulic presses. The molten metal is injected into the die slowly so air and gases can escape ahead of it. After the die cavities are filled, a high injection pressure is applied on the metal as it chills. This tends to prevent formation of shrinkage voids. Machine is fitted with a hydraulic cylinder having a large actuating piston and a hollow piston rod supplying oil to a smaller inner fixed piston. When pressure is applied, the small piston is displaced at high velocity, and moves the piston rod and the main piston forward. Oil then flows through the pre-fill check valve to the space behind the large piston. When the die cavities are filled, oil pressure from a booster pump is applied to both pistons to produce final pressure.



New Induction Machine Features Light Work Unit

Departing from conventional design of high-frequency units, the Ohio Crankshaft Company, has developed a new 7½ kw. output Tocco induction machine with a lightweight work unit separate from the power unit. Connected by cable to the power unit, the mobile top can be moved to facilitate shop operations.

Machine is housed in a rigid welded steel cabinet and is equipped with a vertical-type 220/440 volt, 3-phase, 60-cycle motor-generator set providing 9,600 cycles of high-frequency power.

The lower power unit is 30x36x30 in. in size. It contains the motor generator, cycle controls, air filters and operating meters. The timer and field control switches are located on the side of the cabinet.

The upper or work unit is 20½x17x16⅜ in. in dimension and houses a high-frequency transformer, condensers and a panel for attaching work fixtures or inductor coils. A stop-and-start pushbutton with signal light is furnished.

Compact Winch Control (continued)

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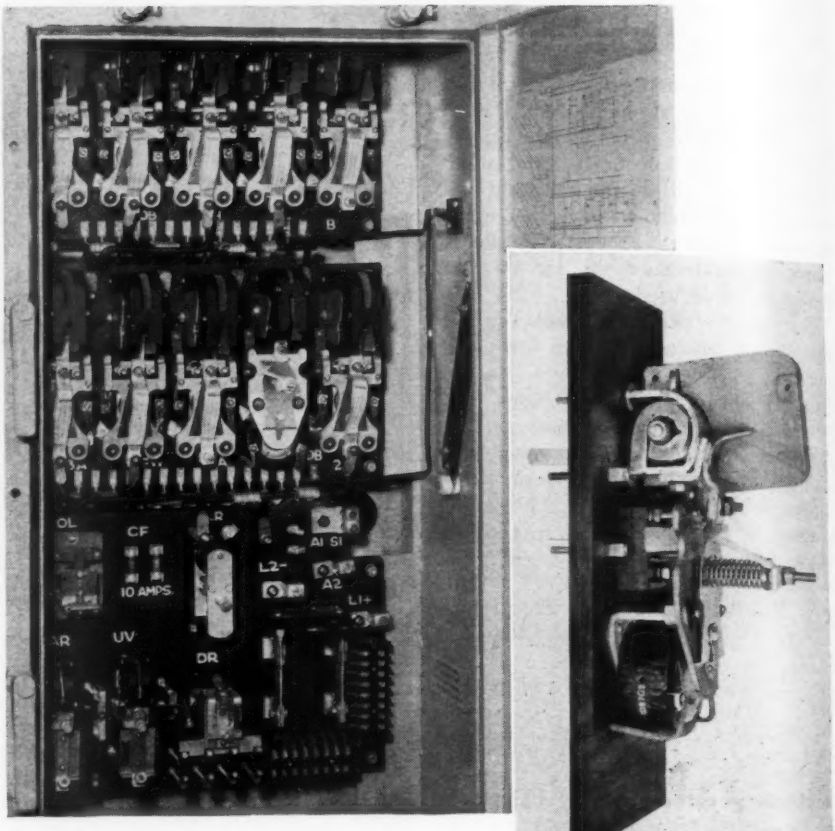

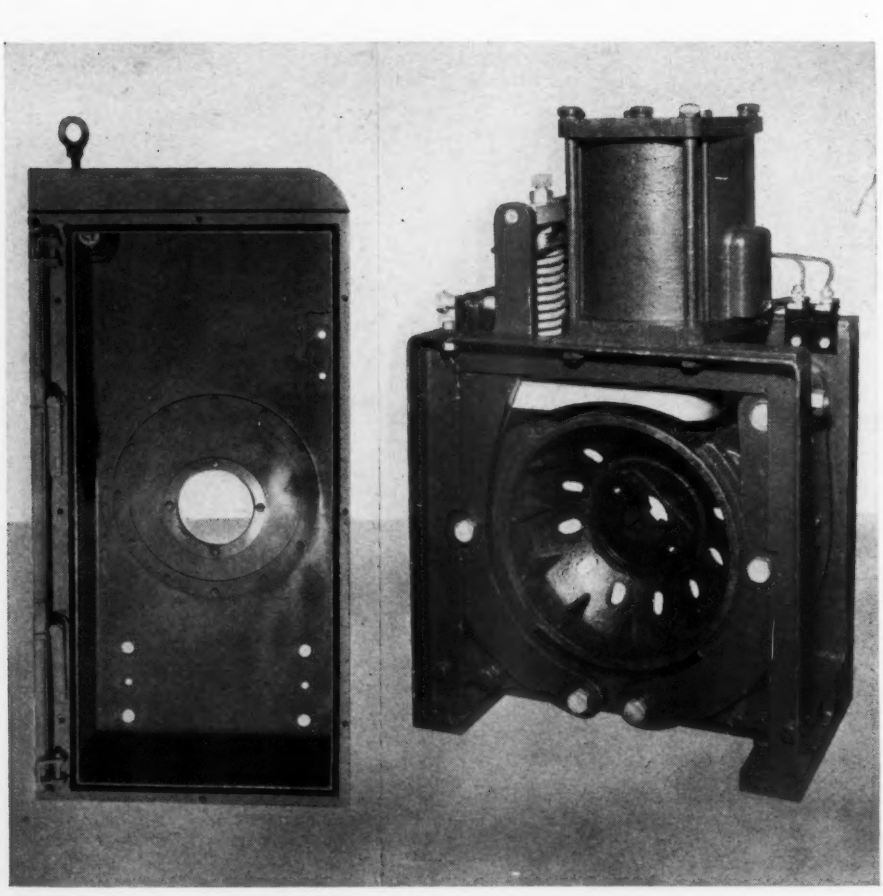

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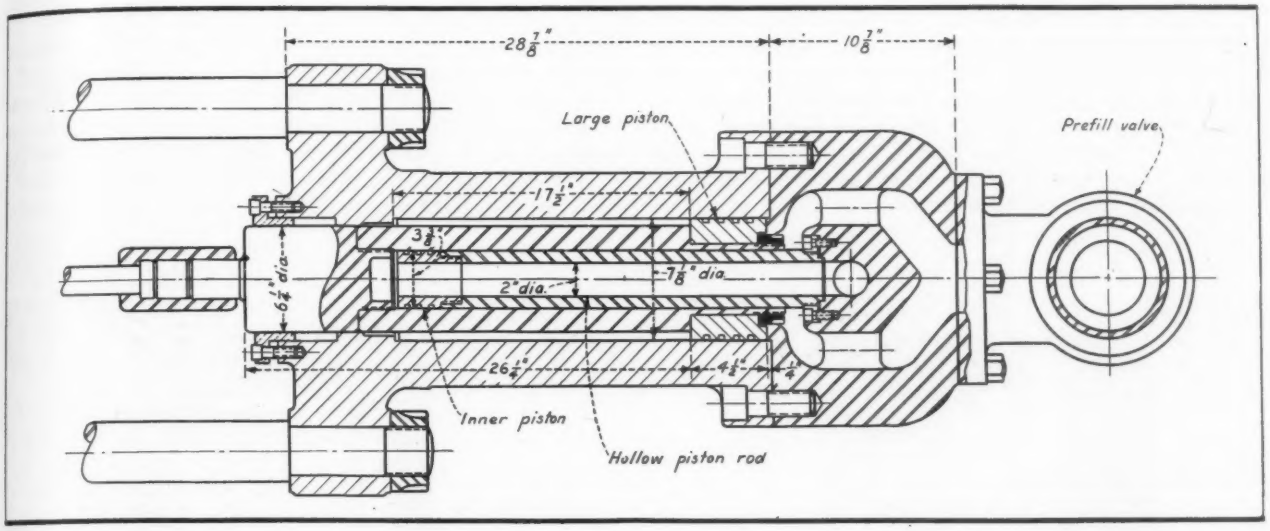

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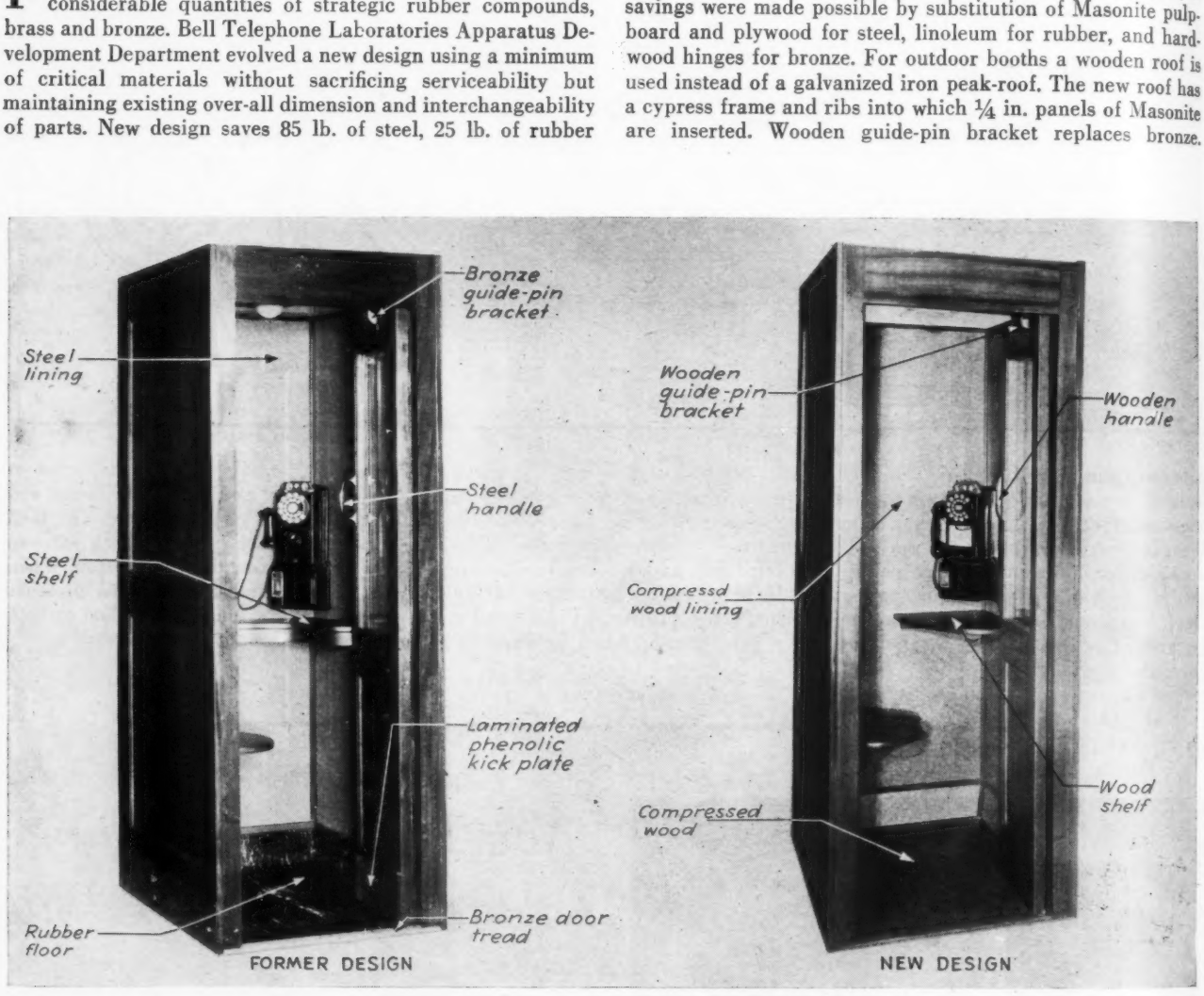
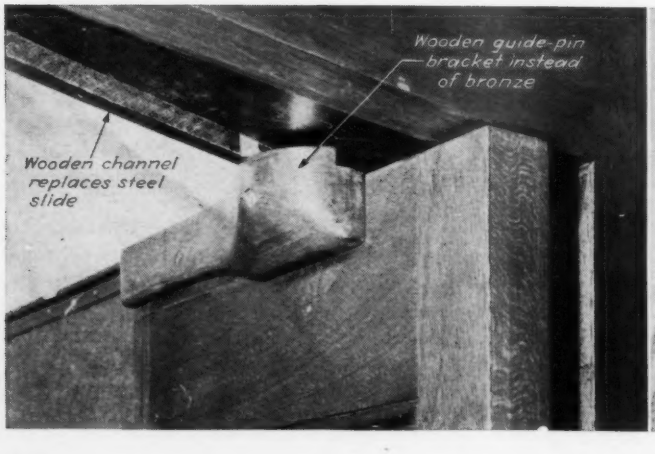
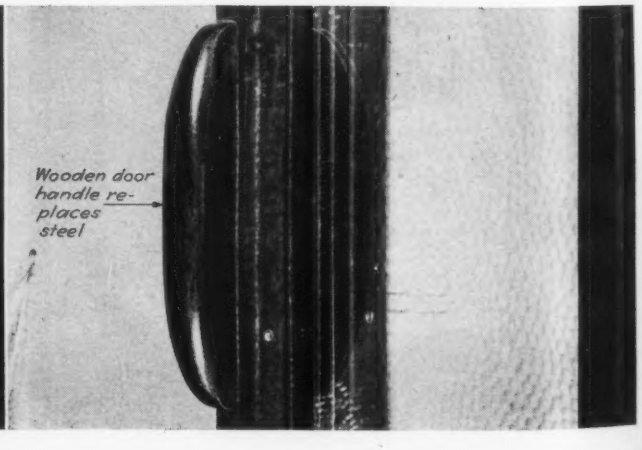
Wartime Phone Booth Saves Steel, Rubber, Brass and Bronze

PRE-WAR PHONE BOOTHS used about 93 lb. of steel and considerable quantities of strategic rubber compounds, brass and bronze. Bell Telephone Laboratories Apparatus Development Department evolved a new design using a minimum of critical materials without sacrificing serviceability but maintaining existing over-all dimension and interchangeability of parts. New design saves 85 lb. of steel, 25 lb. of rubber compound and 10 lb. of brass and bronze per booth. Major savings were made possible by substitution of Masonite pulpboard and plywood for steel, linoleum for rubber, and hardwood hinges for bronze. For outdoor booths a wooden roof is used instead of a galvanized iron peak-roof. The new roof has a cypress frame and ribs into which ¼ in. panels of Masonite are inserted. Wooden guide-pin bracket replaces bronze.

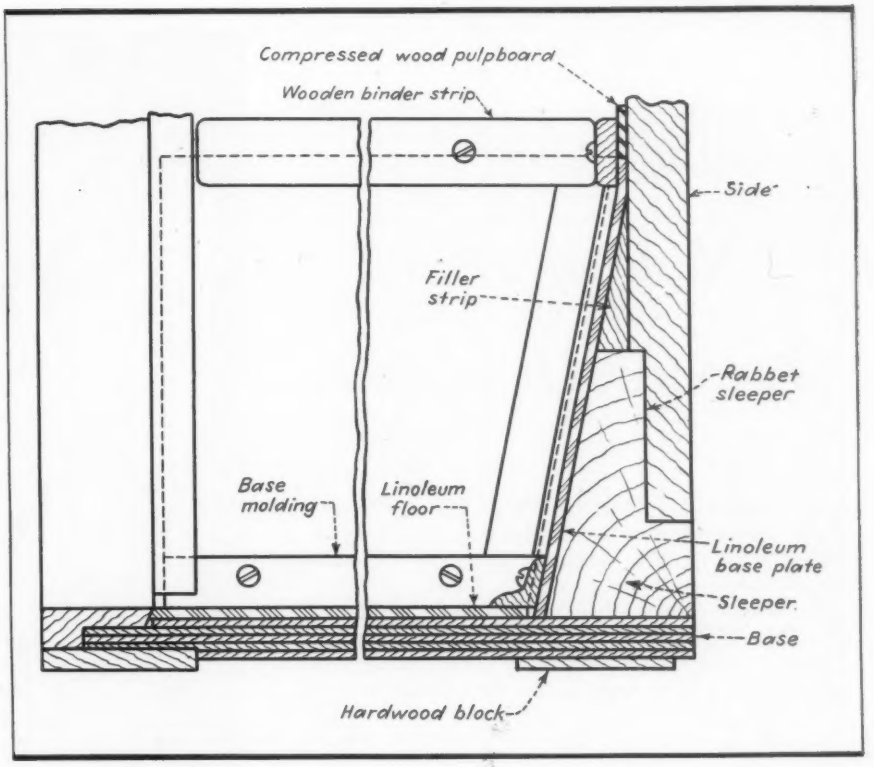




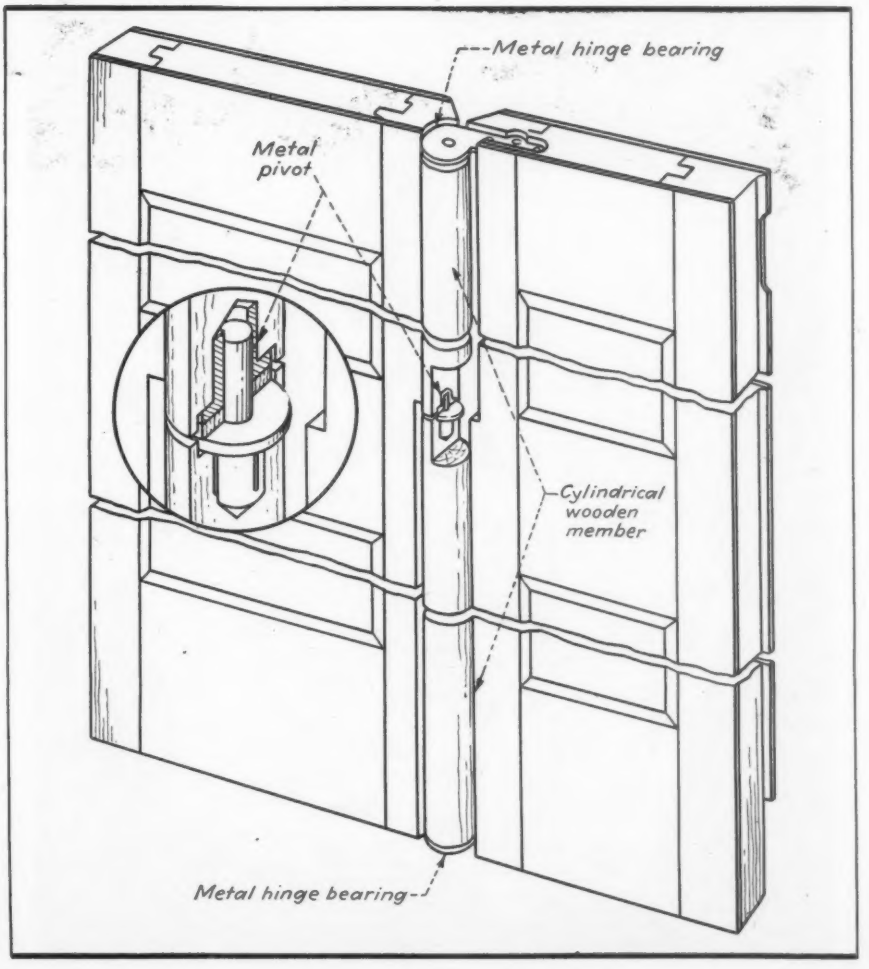


Plywood base is constructed of ½ in. five-ply fir, glued and screwed to birch or maple sleepers. These sleepers fit rabbets in the bottoms of the sides and back of the booth and provide inclined surfaces for supporting the base plates which extend up the sides. Filler strips, attached to the sides and back, continue these supporting surfaces to the required height. Because the base sleepers slope inward, the bottom of the small section of the folding door is tapered slightly to clear it when the door is open. This does not affect the appearance of the door noticeably because the tapered surface is concealed when it is folded back against the side of the booth. Three ⅛x2 in. hardwood blocks are glued and bradded to the under surface, one in the center of the base and one at each of the rear corners. Along the under surface of the front edge is fastened a hardwood strip 2 in. wide. This strip keeps the plywood base from resting directly on the floor. All the exposed surfaces are coated with a protective finish. The base forms a self-contained unit to which the sides, back and door frame are attached with screws. This type of construction preserves knock-down features.

Linoleum was substituted for rubber in the floor covering and interior base plates. A large saving was made by lining the booth with compressed wood pulpboard, instead of sheet steel. This material, of improved appearance, has a hard brown mottled surface. It is not easily scratched or cut and its dark color prevents pencil marks from being easily seen. A wax finish is applied to the material to facilitate cleaning. Pulpboard saved 23 lb. of steel per booth.

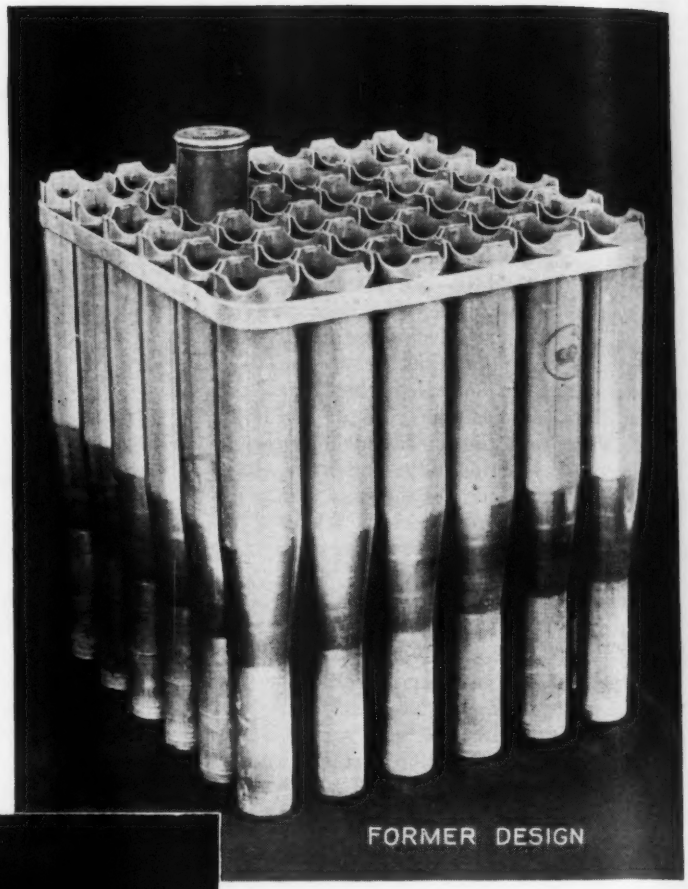


Two-part wooden door hinges are now used instead of a bronze piano hinge to connect the sections of the folding door. The new hinge has two cylindrical wooden pieces, one of which is fastened to the upper part of the larger section of the door and the other to the lower part of the smaller section. The two sections are joined at the center by metal pivots in the ends of the wooden cylinders, and at the top and bottom by metal hinge bearings.

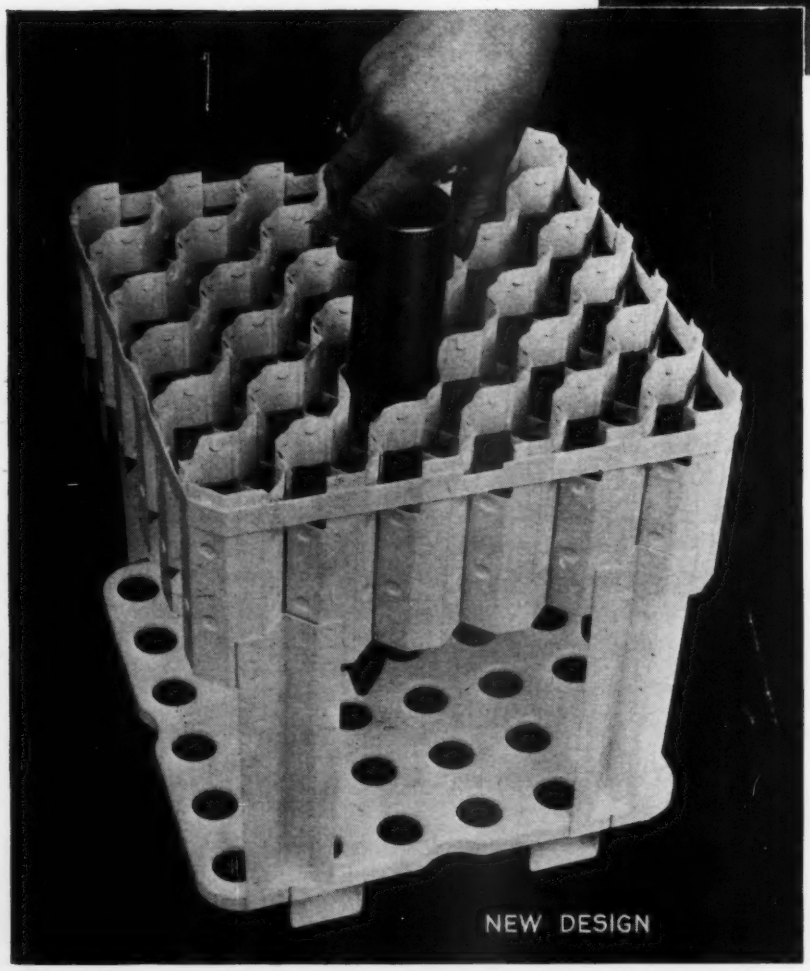


Ammunition Box Made of Steel To Save Aluminum

OCTAGONAL COMPARTMENTS of stamped steel, projection-welded together, have been developed to replace specially machined seamless aluminum tubes for carrying 36 rounds of 1.1-in. Naval ammunition. In designing the new ammunition box, Norris Stamping and Manufacturing Company engineers met the weight specification and retained all the protective features of the former design.



Former design, made entirely of aluminum, consisted of 36 seamless tubes shaped to prevent the highly sensitive fuse from contacting the bottom of the box. Tubes were spot-welded together and surrounded at the top by an aluminum reinforcing band. Dimensional tolerances were close.

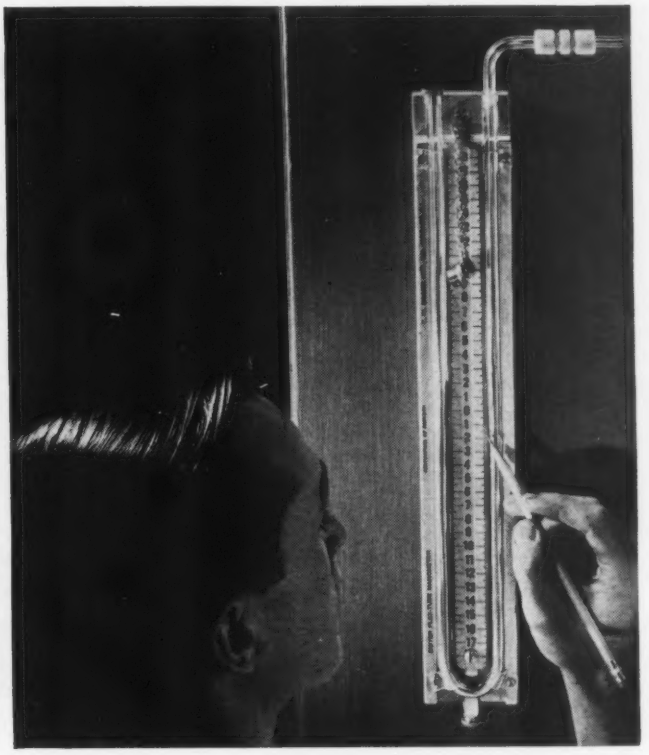


Steel stampings, forming the octagonal compartments of the new design, are embossed at both ends to contact the cartridge case and guide the complete round. The fuse end fits into a bottom plate attached to the nest by four stamped legs. The plate has 36 holes each flanged downward, shaped to conform to the contour of the fuse body, and dimensioned to support the projectile on the fuse body if the latter disengages from the cartridge casing. The sensitive fuse tip projects through the bottom plate but cannot contact the channel-shaped legs of the box bottom. A reinforcing steel band is welded around the top of the complete assembly. Specified dimensional tolerances are held as close as in the original design.

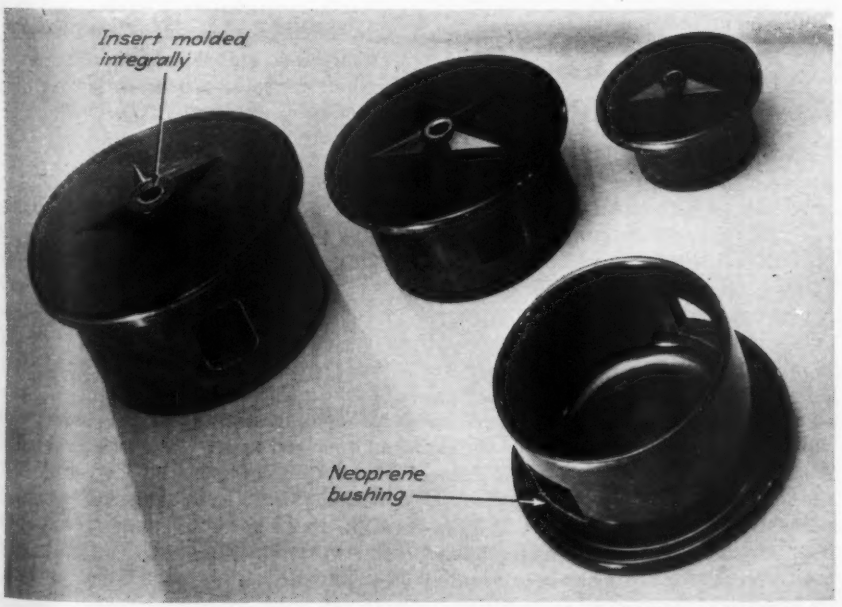
Butyrate Plastic in New Applications

Tennessee Eastman Corporation

Special-type flashlight, in use by the Army Air Forces, has case, bottom cap and top molded of cellulose acetate butyrate. The light bulb is housed at the end of a flexible metal tube. Thus it is possible for the mechanic to place the direct beam of light close to hard-to-get-at points of inspection and the inside of motors. The case is molded by Standard Molding Corporation.



Shatterproof cellulose acetate butyrate replaces glass tubing in manometers for boilers and air-conditioning units. Ends are threaded for screw caps. L-connectors for venting the gages to atmosphere are of slightly smaller diameter tubing tapered and pressed in to make leakproof connections. Manufactured by F. W. Dwyer Manufacturing Company, with tubing extruded by Sandee Manufacturing Company.

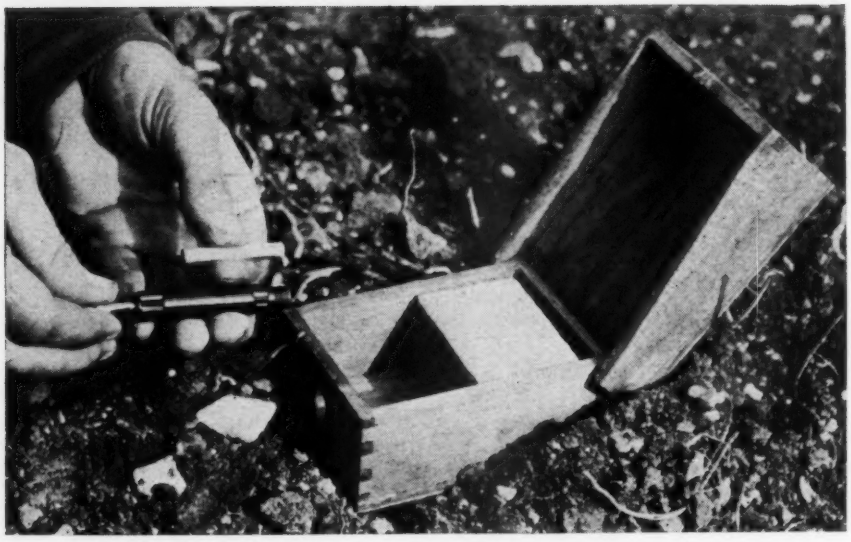


Durez Plastics and Chemicals, Inc.

Phenolic Plastic Replaces Metal In Muzzle Guards

Tompions, used as stoppers to protect gun muzzles and barrels from moisture and dust, are now being molded of phenolic plastic in 3, 5 and 6 in. sizes. A metal insert for the fastening stud is molded integrally. Fitted metal expanders hold the tompions in place. A neoprene bushing fitted into the rim insures a weathertight seal. Advantages of plastics in this application include savings in machining, imperviousness to salt water, grease, oil and corrosion. Molded by Taylor Manufacturing Company and Eclipse Moulded Products.

WARTIME DESIGN NEWS



Wooden Mines

With the development of the electromagnetic mine detector and the training of U. S. and British engineer troops to proficiency with this instrument, the Germans found much of the edge taken off their defensive land mine.

Their answer to the mine detector was the mine shown here, nothing more complicated than a half-pound of TNT placed in a wooden box, which furnishes is own firing mechanism. The use of wood defeats the mine detector and has posed a real problem in detection.

Firing mechanism for this mine is shown in the hands of a doughboy who also holds a cigarette to indicate the size of the detonator. Close examination will show a pin extending through the projection from the left end of the detonator, the opposite end of which is threaded for insertion into the TNT block through the hole in the front of the box. The lid of the wood box fits around the box proper, and when the mine is set, is prevented from dropping all the way down by a twig or similar obstruction. Pressure will force the box completely closed, and the overlapping lid presses the pin downward and out of the striker. A compressed spring hurls the striker forward to detonate a booster charge in the detonator barrel and explode the mine. For booby trapping purposes, a wire can be attached to a ring on the bottom of the safety pin and extended across a foot path.

The man who comes up with a foolproof and relatively simple method of detecting these wooden mines, or the plastic case mines the Germans also have been using, will earn considerable affection from the ground forces, who have encountered many more German mines than they have Germans.

The wooden mine is much simpler, lighter, more compact, cheaper and easier to emplace than the earlier Teller metallic-cased mine.

Army Developments

An Ordnance sergeant has developed a governor for air compressors which saves 11 to 15 percent of the gasoline used by models now in service at home and abroad with U. S. troops. The governor reduces idling speed of compressor motors, taking over when the compressor is not under load. On small, mobile compressors the governor reduces idling speed 34 percent, cuts gas consumption 15 percent and lowers exhaust temperatures 13 percent. On the Army's large (16 cu. ft.) compressor, the governor reduces idling speed 30 percent, cuts fuel consumption 11.5 percent and reduces exhaust temperatures two percent. A patent has been granted its inventor.

New Compasses Better

Another new Army development is the wrist compass, replacing the inaccurate watch compass previously issued field troops. The new wrist compass eliminates the principal fault of the watch compass, a pronounced tendency for the needle to swing off its mark on the slightest disturbance, by mounting the needle in liquid which is enclosed in a plastic retainer. The same device was used in redesigning the "lensatic" compass, a larger and more elaborate compass which included a hairline and lens sighting device.

The new compasses are waterproof, eliminating the misting which formerly obscured dials. Their needles give accurate readings on the back of a jogging horse. Cases are also of plastic.

Nylon for Cotton

The Quartermaster Corps has substituted Nylon for cotton fabric in the ponchos issued troops in tropical combat areas. Approximately the same synthetic resin which was used to impregnate the earlier cotton model is used on the Nylon poncho, which at 30 oz. is only about half the weight of the 55-oz. cotton poncho. The new garment, preferred by fighting men to regular raincoats, is made with grommets and eyelets which allow it to be used as a tent when laced together with another. Other uses are as a ground sheet, a foxhole cover or a bedroll. It may even replace the shelter-half.

"Tiger" Tamed

On the basis of accumulated battle data, the Ordnance Department claims that three of its weapons are superior to the German's 62-ton Mark VI "Tiger" tank, the mightiest vehicle the Germans have yet unveiled. Masters of the "Tiger," says Ordnance, are our M-10 tank destroyers, a 3-in. gun mounted on a medium tank chassis with an open top turret (PRODUCT ENGINEERING, Apr. 1943, p. 193), the M-7 "Priest," a 105-mm. howitzer mounted on a medium tank chassis (PRODUCT ENGINEERING, Mar. 1943, p. 129), and the 90-mm. all-purpose anti-tank-anti-aircraft gun.

Battle reports show that one shell of the M-10's 3-in. gun will destroy a Mark VI. The "Priest's" 105-mm. howitzer fires a heavier shell than the "Tiger's" 88-mm. projectile, and the 105 shell carries a greater explosive charge. The 90-mm. U. S. weapon outranges the 88 with a heavier projectile and fires faster and more accurately. It is less complicated in manufacture and operation than the 88, which can be traversed only three times before "unwinding."

New Engine Fan

A small fan mounted directly behind an aircraft propeller to blast air over the cylinders of an air-cooled engine has been developed by the Wright Aeronautical Corporation in conjunction with the Air Forces. The new device delivers a high-pressure flow of air through the cowling even when exit flaps are closed, exhausting the air into the slip stream with considerably less drag than is normally the case. Rate of climb may be boosted as much as 20 percent with the fan, and the payload of some twin-engine craft is upped as much as five tons. By cutting down drag, the fan vastly increases the horsepower available for forward motion.

Manpower Resolved

Barring a disastrous failure in the forthcoming invasion of Europe proper, or some similar disaster, the manpower question now is pretty well settled in a course which will take virtually all physically-fit men under 26, many between 26 and 30 and relatively few more who have passed 30. If it were decided to raise the size of the armed forces beyond the projected 11,300,000 men, the pattern, of course, would be changed.

Two factors have combined to spare appreciable further inroads upon the men in their 30's, one the desperate need of the services for the resiliency of youth in combat, and the other the fact that most war production is sufficiently well in hand to merit the gamble of curtailing further production by drafting the youthful key men.

The extent to which the high command ever counted upon aerial bombardment to knock out the enemy is unknown, but the Italian campaign has proved that whatever else is available, tough infantry—and in numbers—must be available not only to occupy territory but to drive out whatever enemy hangs on through whatever aerial assault is hurled at him. The services, of course, would have been happy if they had never needed to take a man over 28, but they are now determined to take as few over 30 as they possibly can.

Deferments Under 26 Rare

The highly critical programs such as radar, high-octane gasoline, rubber, landing craft, rockets, secret weapons, heavy truck components and some others will keep a few key technical men under 26, a provision rather reluctantly agreed to by the services. The figure runs currently to 50,000 or 75,000 men, specifically picked by industry, plant and job. The remainder have been slated to fight with the weapons

Captured German Self-Propelled Gun Has Steel Treads

Signal Corps Photo

German self-propelled 75-mm. gun (left) is being towed away by a U.S. tank retriever. The Germans mounted a 75 on their Mark III medium tank chassis to match our M-7 and M-10 tank destroyers and other self-propelled artillery. The U.S. tank retriever apparently is adapted from an early riveted M-3 "General Grant" tank. The turret has been removed and a crane installed, along with other superstructure. The circular turret is probably a mount for a .50-cal. anti-aircraft machine gun. Simplicity features the U. S. running gear compared with that of the German vehicle. U.S. tracks are rubber-shod, while the tracks of the German tank are steel-shod.

Armored Car Used for Combat Reconnaissance

U.S. Army Photo

Army's M-8 armored car (PRODUCT ENGINEERING, Apr. 1944, p. 232) for combat reconnaissance, has a turret-mounted 37-mm. cannon and carries a .30-cal. machine gun. It is operated by a crew of four. Earlier U.S. vehicles used for this purpose had armor slung on a normal truck chassis, but the M-8 has a fabricated hull.

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they have developed and produced. Not all the remainder will be physically acceptable, of course. But those who are will go in. Whatever gap is left between the total of all men inducted and the 11,300,000 over-all goal for the armed forces will be filled on a slightly less drastic basis by men in the 26–30 age bracket. To the extent that more men are needed, they will be inducted from the age groups above 30, with men in essential industries and fathers given some slight preference where all other factors are equal. It is not expected, however, that there will be much dipping into age groups above 30.

Fewer Victory Optimists

Many observers agree that when the European war has been won, inductions can be slowed drastically, limited perhaps to those of boys reaching 18. If this be so, a possibility exists that the draft may be ended this year, but virtually no responsible officials in Washington endorse this idea as a sound basis for operation of an industrial property. While there is an air in Washington of marking time awaiting the success of the projected invasion, there is distinctly less feeling that the German war is as good as over and that a resounding triumph in the invasion will bring on Germany's defeat within a matter of weeks or a few months.

Patent Hearings Planned

Washington's Senator Homer T. Bone has been nominated by the President for a judgeship on the Federal Circuit Court covering seven western states, Alaska and Hawaii, but he plans to remain in the Senate long enough to preside over further hearings by the Patents Committee, which he heads.

Plans for the hearings are indefinite, with Bone again hospitalized for treatment of an old leg injury, operations on which kept him away from the Senate much of last year. A committee aide indicated that little of a concrete nature has been determined with regard to further hearings to complete the lengthy investigation of suggested patent reforms and cartels which Bone's committee held in 1942. Bone has insisted, however, that he intends to give critics of his voluminous patents record an opportunity to be heard. No date for further hearings has been set.

Bone almost certainly will retain his seat until after next fall's election to preclude an interim Republic appointment by Washington's governor.

Sen. Ellison D. Smith, South Carolina Democrat, follows Bone in seniority among Democratic members of the committee, but being chairman of the Agriculture Committee, he would be barred from holding a second chairmanship and there is little prospect of his resigning the important Agriculture committee post for chairmanship of the Patents Committee. Following Sen. Smith in seniority are Claude Pepper, Florida, and D. Worth Clark, Idaho. Each of these men come up for re-election next fall.

Ever-Better Fighting Equipment

THERE has been so much talk about cut-backs and cancellations of war contracts that some people have gained the erroneous impression that this nation is about finished with the job of building war equipment. To keep the facts straight, it can be pointed out that the United States is hardly started in the manufacture of many military items and others are still on the drawing boards. The truth of the matter is that new superior weapons and implements of war will be in the process of development as long as the war lasts.

Necessity for military secrecy veils from public view the many new pieces of war equipment now in various stages of development. Only after a new plane, gun, tank or other unit has seen service, or at least until the knowledge of its existence has leaked out, is it officially announced. Many know now that Boeing engineers sweated for years to design the B29 airplane, that we have amphibious tanks, that new devices aim and fire anti-aircraft guns with uncanny speed and precision, and that new submarine detectors doom the underwater boat to destruction once it gets "on the beam."

It is perhaps not generally appreciated that there has been no let-up in the intensity of the product development program which has in less than four years overshadowed the best Hitler could do in ten years. Military secrecy prohibits divulging details but it is of no comfort to the enemy to mention that further improved designs of every type of fighting equipment are well underway.

On the flying field of one aircraft manufacturer can be seen a new phantom of the air streaking across the skies at record-breaking speeds. Elsewhere in a laboratory one can see, undergoing a shake-down test, a new fighter, bigger, faster and more heavily armed than the ship it replaces. A peek into the hydraulic laboratory of another aircraft plant shows a full sized replica of the complete hydraulic system of a new monster of the air that is in the last stages on the drawing boards. Going to another kind of a plant one can see a variety of mobile units, the like of which is new to combat services, going through its paces.

Not all of the design attention is being given to large equipment. The last word in bombsights is still on drawing boards. Signal Corps apparatus is being improved continuously. The same can be said of the materiel for all the other branches of the services.

In addition to the development of new models and equipment, much of the present activity is in design refinements to simplify production problems, to make servicing easier, to improve fighting power, to modify weapons to meet special conditions or to increase the efficiency of the units. Some idea of the magnitude of this job and the intensity with which it is being prosecuted can be gained from the fact that more scientists and engineers are now working on design improvements than were engaged in developing the original designs. Their efforts show visible results.

All of the work on the design of war equipment is proceeding with such secrecy that the public is hardly aware of it. But all can rest assured that the enviable record made thus far is merely the curtain raiser for the more startling things yet to come.

G. F. Nordenholt

Aircraft Fuselage Openings Require Study for Stress Transfer

GAIL SWAN
Chief of Structures, Kaiser Cargo, Inc., Fleetwings Division

Analysis of arbitrary approximation of a spar with lightening holes cut in its web making it a discontinuous section, and a simplified method for analyzing major closed structures such as a semi-monocoque type of fuselage in which a large cut-out transforms the structure into an open section.

ONE important current problem in airplane structural design is the analysis of failure at discontinuous sections, such as cockpit openings, doors, and access holes. Cut-outs in a structural member destroy the main continuity and carry-through of the member and require a redistribution of load for its transfer through the cut-out region.

In semi-monocoque fuselage design, stringers running the length of the fuselage are assumed to carry the bending stresses developed under any flight condition. When the continuity of a stringer is broken, the axial load being carried in that stringer must be transferred to those adjacent which are continuous. Also when a shear panel is designed with access holes, the shear that was carried by the full depth of the panel must be transferred to only that portion of the panel that is continuous, and thence carried across the cut-out region.

The first condition of discontinuous stringers introduces an indeterminate analysis which is usually attacked only in research problems. In standard analyses, assumptions are made as to the effective area of the discontinuous stiffeners. They are assumed to be entirely ineffective at the cut-out region and to be fully effective approximately one or two bays each side of the cut-out. Although this method of analysis is only an arbitrary approximation, it offers a simple method for predicting the strength of the structure on both sides and in the region of a major cutout. The second condition of a partially discontinuous shear web is subject to direct analysis.

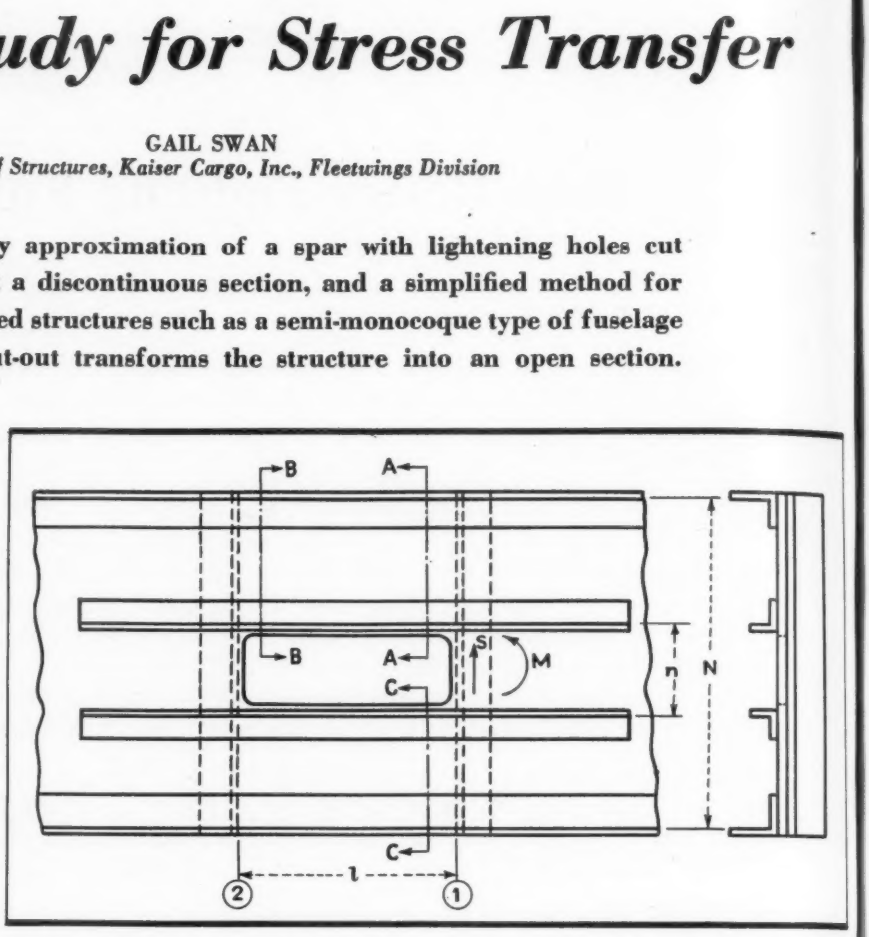


Fig. 1—Section of a spar with a cut-out in the web. When the shear loads in the web are low or the length of the cut-out is small, the reinforcing angles are not required.

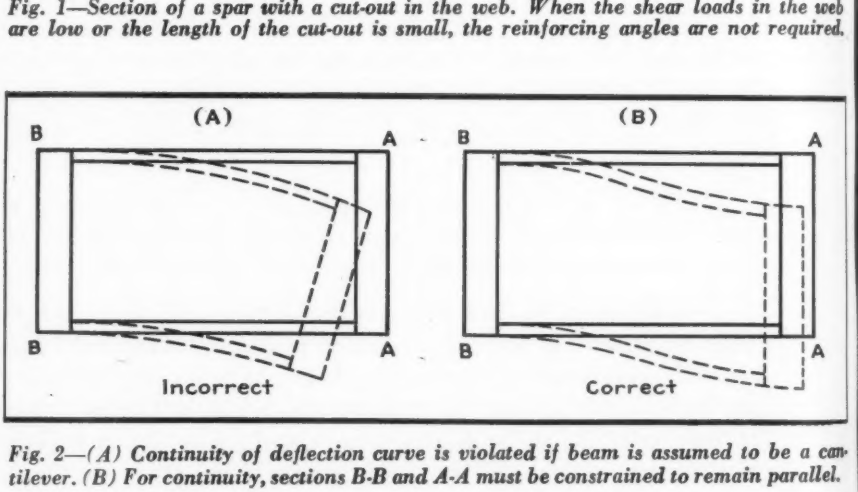


Fig. 2—(A) Continuity of deflection curve is violated if beam is assumed to be a cantilever. (B) For continuity, sections B-B and A-A must be constrained to remain parallel.

SPAR WEB CUT-OUT. When a web cut-out is incorporated in the design of a spar, the shear that was originally carried by the full depth of the spar must be transferred through the cut-out region only by that part of the shear web that is continuous. In the spar design shown in Fig. 1, the shear load S will be transferred by the stiffener at Station 1 to sections *A-A* and *C-C*. That portion of the shear load taken by section *A-A* will be KS, which in being transferred across the cut-out region to section *B-B* introduces a secondary bending moment

$$M = KSl$$

If this moment is considered as being resisted entirely by section *B-B*, with the upper beam acting as a cantilever fixed at *B-B*, Fig. 2 (*A*) the deflection continuity at section *A-A* will be violated, since it would necessitate a sharp break in the deflection curve at that section, exactly as if that section had no rigidity (pin connection). Thus to preserve continuity the structure must act as a picture frame, Fig. 2 (*B*), with the

secondary bending moment resisted by both sections *A-A* and *B-B*. Since the transfer requires continuity of the elastic curve, the analysis must be based on relative rigidities.

The shear load *S* is carried by the upper and lower local beams, Fig. 1, in direct proportion to their relative moment of inertias, so that the vertical deflection of section *A-A* will be of the same magnitude as that for section *C-C* with respect to Station 2. Then in transferring this shear load across the length *l*, the local bending moment *KSl* will be resisted by both sections *A-A* and *B-B*, also in direct proportion to their moments of inertias. From the elastic curves shown in Fig. 3, it is seen that this introduces between these two sections an inflection point at which the secondary bending moment is zero.

The structure, therefore, may be analyzed by cutting the main beam through the inflection points of the local beams, as shown in Fig. 4, then calculating the reactions at this section and analyzing for the loads on the isolated structure.

At section *A-A* where

P = axial load on section
M = bending moment at Station 1
h' = distance between center lines of axial loads on each side of cut-out
S = shear load at section
l = length of cut-out
I_A = moment of inertia of section *A-A*
I_B = moment of inertia of section *B-B*

$$P = \frac{M}{h'} + \frac{Sl}{h'}\left(\frac{I_A}{I_A + I_B}\right)$$

$$M = S_A l\left(\frac{I_A}{I_A + I_B}\right)$$

The secondary bending moments are balanced out within the bays (1) to (0) and (2) to (3). This region must be checked for the high shear loads which result from this redistribution of secondary moments.

For smaller cut-outs the analysis is the same. But the secondary loads introduced are small. They can be carried by an outstanding flange around the cut-out. Often even flange or edge reinforcement is not necessary. The size of cut-out and the amount of shear load to be transferred are the determining factors.

CUT-OUTS IN CLOSED SECTIONS. When a large cut-out is made in a closed fuselage section, the question of shear distribution and torsional load transfer becomes a major problem. Torsion-bending, shear stress concentration and excessive deflections are introduced. An exact solution of these effects is too complicated to be practical for analysis purposes. Therefore, approximations are made as to the nature of the stress distribution, and an analysis carried through on a conservative basis only for the purpose of indicating critical stresses or deflections.

Cut-outs in airplane design such as cockpit openings and tail wheel cut-outs, are usually symmetrical with respect to the vertical center line of the airplane. This type of cut-out is subject to a fairly direct analysis with respect to symmetrical loads since the vertical shear can still be carried by the continuous sides of the structure, and the bending loads are resisted by continuous stringers or additional reinforcements on the sides of the cut-out. But side shear loads, and hence torsional moments, introduce

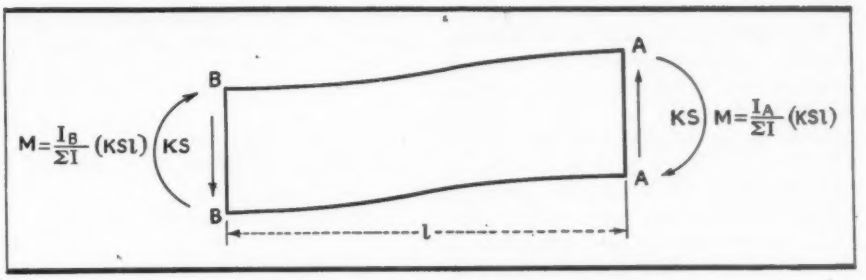


Fig. 3—Elastic curve of web between sections B-B and A-A resulting from local bending moment.

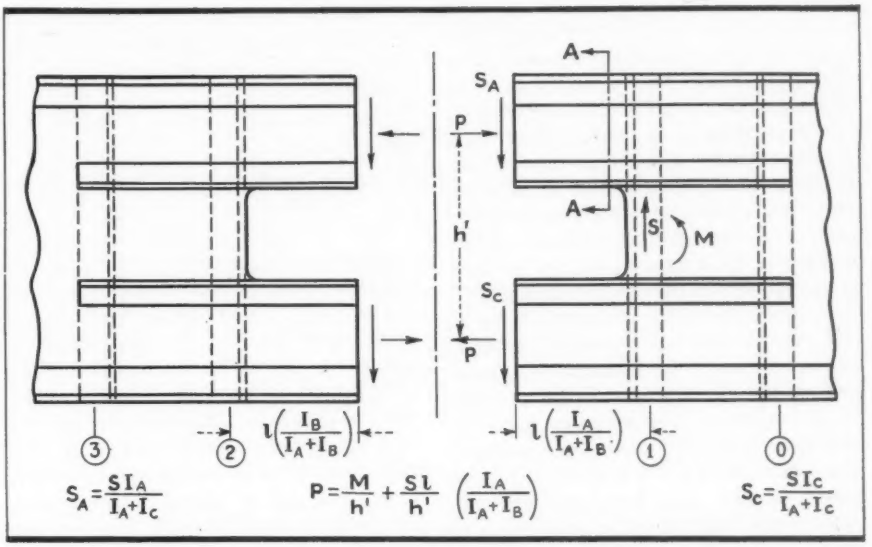


Fig. 4—Diagram for analyzing the reactions in the main beam at inflection points where secondary bending moment is zero.

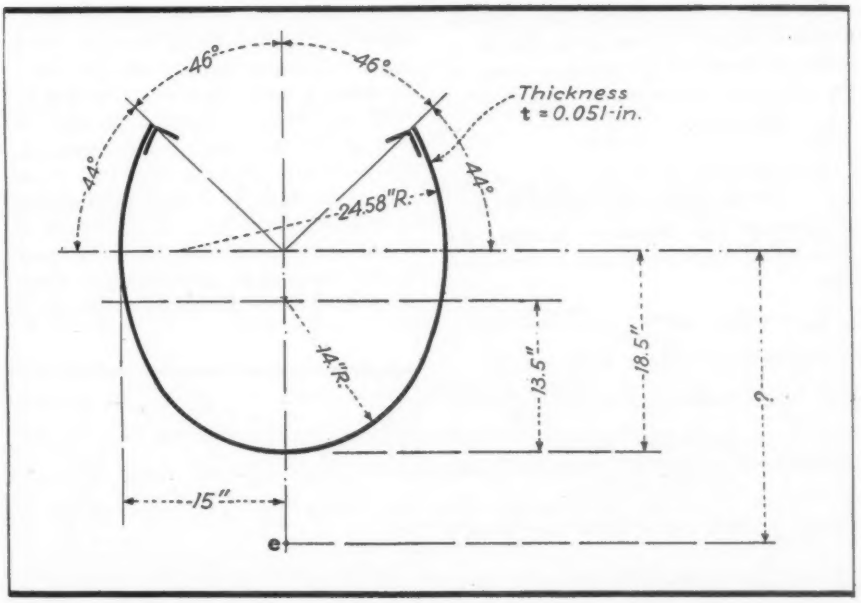


Fig. 5—Section of fuselage with cut-out for cockpit opening.

difficult distribution analysis problems.

A simplified procedure is as follows. Consider the fuselage section, shown in Fig. 5, on which the vertical tail imposes a side load of 655 lb. and a torsional moment about the *X-X* reference axis of 21,943 in. lb. The first step is to calculate the shear center *e*, the point at which the side shear force must be applied to prevent torsional deflection in the open section. This can be done either analytically by calculating the longitudinal running shear at several stations along the skin line and finding the summation of these moments about any convenient axis, or by formulas from *N.A.C.A.-T.N.* 691, "Elementary Principles of Shell Stress Analysis With Notes on the Use of the Shear Center."

The location of the shear center *e* depends entirely upon the assumptions made as to the distribution of bending material, since this distribution determines the longitudinal running shear, and hence the distance from the fuselage reference axis to the shear center. Therefore, fairly accurate assumptions as to the distribution of bending material should be made, by taking into consideration the effectiveness of the material of the section. Compression buckling and even shear-lag must be considered. For example, when the section is composed of four rigid longerons with the inter-connecting thin skin only acting as shear webs, the longitudinal running shear can be assumed to be constant between the longerons, thus greatly simplifying the calculations.

For simplicity, assume the section shown in Fig. 5 to be a circle, Fig. 6, of radius R equal to the mean average of the elliptical semi-axes, or

$$R = \frac{18.5 + 15.0}{2} = 16.75 \text{ in.}$$

θ = half the angle of cut-out, deg. = 46
α = θ expressed in radians = 0.803

Neglecting the stiffeners because of their small area compared to the skin area

$$I_{yy} = \pi R^3 t - \alpha t R^3 \left[1 - \frac{\sin\alpha \cos\alpha}{\alpha}\right]$$

$$= \pi \times 16.75^3 \times 0.051 - 0.803 \times 0.051 \times 16.75^3 \times \left[1 - \frac{0.719 \times 0.695}{0.802}\right]$$

$$= 754 - 73 = 681 \text{ in.}^4$$

with Q_θ equal to the static moment of area at any angle θ

$$Q_\theta = \int_{46^\circ}^{\theta} x\,dA; \quad dA = Rd\theta t; \quad x = R \sin\theta$$

$$Q_\theta = \int_{46^\circ}^{\theta} R\,t\,R \sin\theta\,d\theta$$

$$= -\left[R^2 t \cos\theta\right]_{46^\circ}^{\theta}$$

$$= -R^2 t \cos\theta + R^2 t \cos 46 \text{ deg.}$$
$$= 0.695 R^2 t - R^2 t \cos\theta$$

with q_θ equal to the longitudinal running shear at angle θ in lb. per sq. in. and P equal to the applied side load in pounds

$$q_\theta = \frac{P Q_\theta}{I_{yy}} = \frac{P}{681}\left(0.695 R^2 t - R^2 t \cos\theta\right)$$

Taking moments of these running shear loads about the center of the circle

$$M_e = 2\int_{46^\circ}^{\pi} \frac{P}{681}\left(0.695 R^2 t - R^2 t \cos\theta\right) \times R^2\,d\theta$$

$$= \frac{2PR^4 t}{681}\int_{46^\circ}^{\pi}\left(0.695\,d\theta - \cos\theta\,d\theta\right)$$

$$= \frac{2PR^4 t}{681}\left[2.18 - 0.558 + 0.719\right]$$

$$= \frac{2P \times 16.75^4 \times 0.051 \times 2.34}{681} = 27.7P$$

Therefore

e = 27.7 in from X-X axis.

After the location of the shear center is found, the torsional moment of the applied force about the shear center is calculated.

The torsional moment T about the shear center is

$$T = 21{,}943 + 655 \times 27.7 = 21{,}943 + 18{,}150 = 40{,}093 \text{ in. lb.}$$

This torsional moment can only be reacted in an open section by equal and opposite shear loads on the two sides of the section. These shear loads cause equal and opposite bending which is commonly called "torsion bending." The distribution of these shear loads on the sides of the section is also indeterminate in a simplified analysis, and is arbitrarily assumed to be distributed uniformly along a specified length. This assumption is fairly accurate only for a section similar to that mentioned in the previous paragraph, that is, one consisting of four rigid longerons and interconnecting shear webs. A more exact solution can be obtained by calculating the longitudinal shear that would exist by assuming a certain portion of each side acting as separate beams in torsion bending.

At any point in the section the running shear, therefore, is the summation of the shear resulting from the transverse load and the shear resulting from the torsional moment. It should be remembered that assumptions are made for the purpose of simplifying an analysis, and thus the assumptions should be based on experience of the behavior of the material and determined by the requirements of continuity in deflections and stresses.

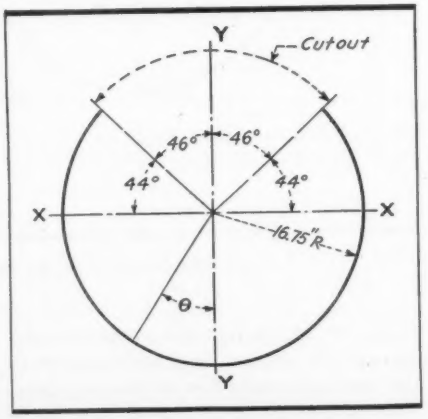


Fig. 6—Assumed circular section at fuselage cutout for simplified calculations.

The axial stresses in the section will be those resulting from the beam bending moment at the section plus those which result from torsion bending. When making an analysis for the torsion-bending stresses, careful consideration should be given to the fixity of the beams and the apparent location of their inflection points.

Considering this torsion to be resisted by uniform shear stresses in the two side arcs having an angular length of 88 deg., the girth length c of skin in shear is

$c = R\,\theta = 16.75 \times 88/57.3 = 25.8$ in.
q_s = skin load resulting from longitudinal shear
q_p = skin load resulting from torsion about shear center

$$q_p = \frac{40{,}093}{25.8 \times 16.75 \times 2} = 46.4 \text{ lb. per in.}$$

$$q_s = \frac{P}{681}\left(0.695 R^2 t - R^2 t \cos\theta\right)$$

at $\theta = \pi/2$, $q_s = \frac{655}{681} \times 0.695 \times 16.75^2 \times 0.051 = 9.58$ lb. per in.

at $\theta = \pi$, $q_s = \frac{655}{881} \times 1.695 \times 16.75^2 \times 0.051 = 23.4$ lb. per in.

at $\theta = \pi/2$, $q_s + q_p = 46.4 - 9.58 = 36.82$ per in.

Skin stress $f_s = \frac{36.82}{0.051} = 721$ lb. per sq. in.

at $\theta = \pi$, $q_s + q_p = 23.4 + 0 = 23.4$

Skin stress $f_s = \frac{23.4}{0.051} = 459$ lb. per sq. in.

In side bending,

skin stress $f_b = \frac{94{,}000 \times 15.0}{587.3} = 2{,}400$ lb. per sq. in.

Using the parameter R/t to determine the allowable stress in a monocoque structure.

$$R/t \text{ of sides} = \frac{24.58}{0.051} = 483$$

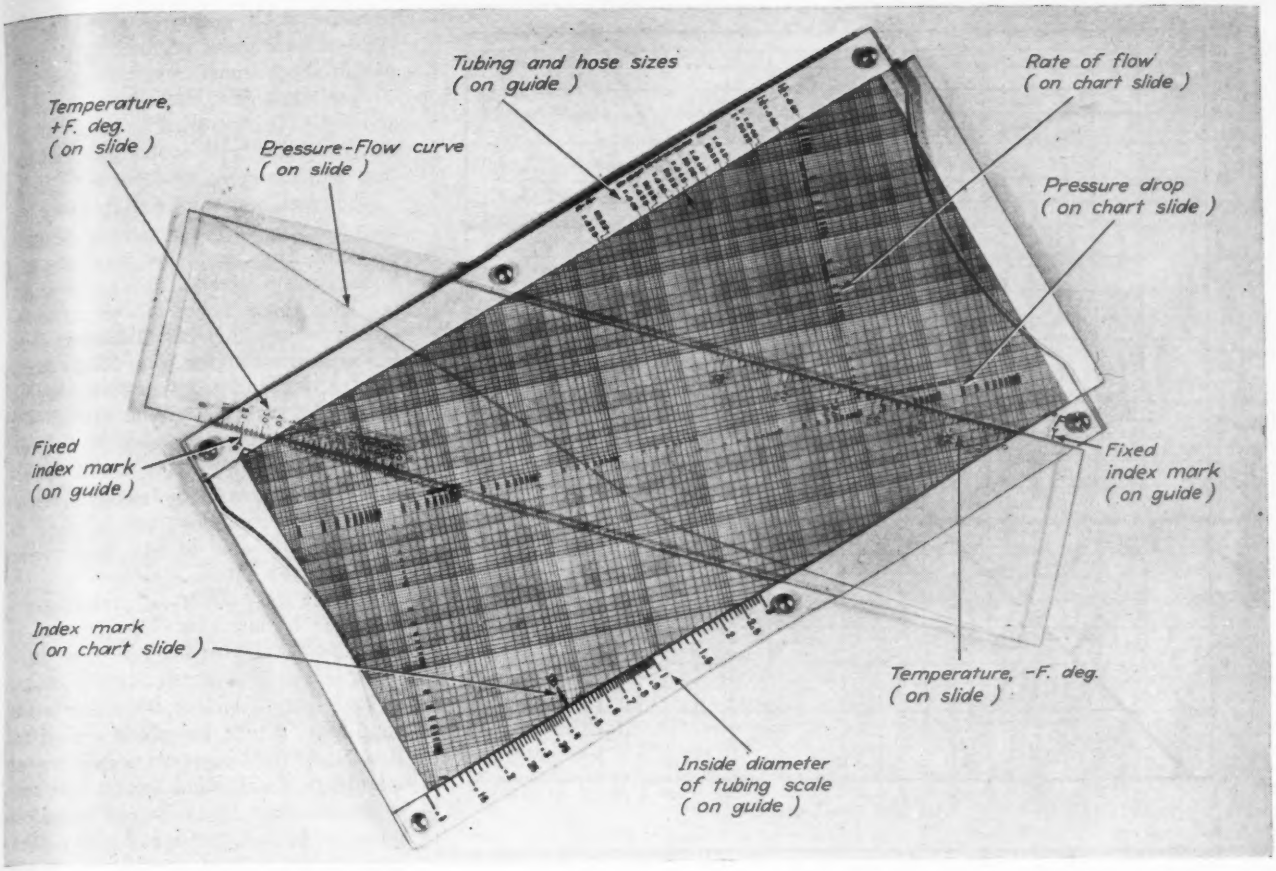
$F_b = K_b E = 0.009 \times 10^7 = 9{,}000$ lb. per sq. in.
$F_s = 3{,}160$ lb. per sq. in.

$$R_b = \frac{2{,}400}{9{,}000} = 0.267$$

$$R_s = \frac{721}{3{,}160} = 0.228$$

$$R_b + R_s^2 = 0.267 + 0.052 = 0.319$$

Analysis computations have been reduced greatly for presentation in this article. Through the use of simplifying assumptions, a minimum of calculations has been shown to illustrate the basic principles. A more exact analysis may be performed where stresses are of large magnitude and an accurate determination of the failing load is necessary. The refinements added to the analysis will depend entirely upon the exact application and must be determined by the analyst. The methods of analysis discussed in this article can be applied directly in preliminary design.



Simplified form of pressure drop calculator constructed for given fluid. For any given temperature and pipe-size setting, the common intersection of "Pressure-Flow Curve," "Rate of Flow" and "Pressure Drop" gives the answer. Any one of the four factors may be the unknown quantity. As set, the calculator indicates that the fluid when flowing at the rate of 6 g.p.m. through ½ × 0.042 in. tubing, a temperature of 21 deg. F., will have a pressure drop of 0.2 lb. per sq. in. per in. of length.

Hydraulic Calculator Solves Pressure Drop Problems

J. JEROME
Hydraulic Research Engineer, Consolidated Vultee Aircraft Corporation

Device for calculating the pressure drop of fluid flowing in any given size of pipe or tubing for known conditions of viscosity, temperature and rate of flow. Hydraulic pressure drop and flow formulas are stated from which data are developed and used to construct chart plate and reference base lines.

MOLECULAR friction in a fluid flowing through a pipe creates a drag that is measured as a difference in pressure at the inlet and outlet ends of the pipe. This pressure drop is of great importance in all liquid transmission systems whether they be in aircraft, machine tools, construction machinery or other equipment.

Since pressure drop is a function of pipe or tubing diameter, wrong pipe size might result in not enough flow or pressure at some connected unit. In airplane design, tubing that is larger than necessary means useless cost and weight.

There are several methods of calculating the correct size of conduit for liquids for a given set of conditions, but each involves the use of large wall or desk charts, or the solving of cumbersome equations. Many methods require more than a dozen steps, plus time-consuming calculations that involve the possibility of mathematical error upsetting the final answer. All this is eliminated by the calculator described here, which reduces the solution of the problems to setting a couple of scales and reading the results.

The device is essentially a plot of

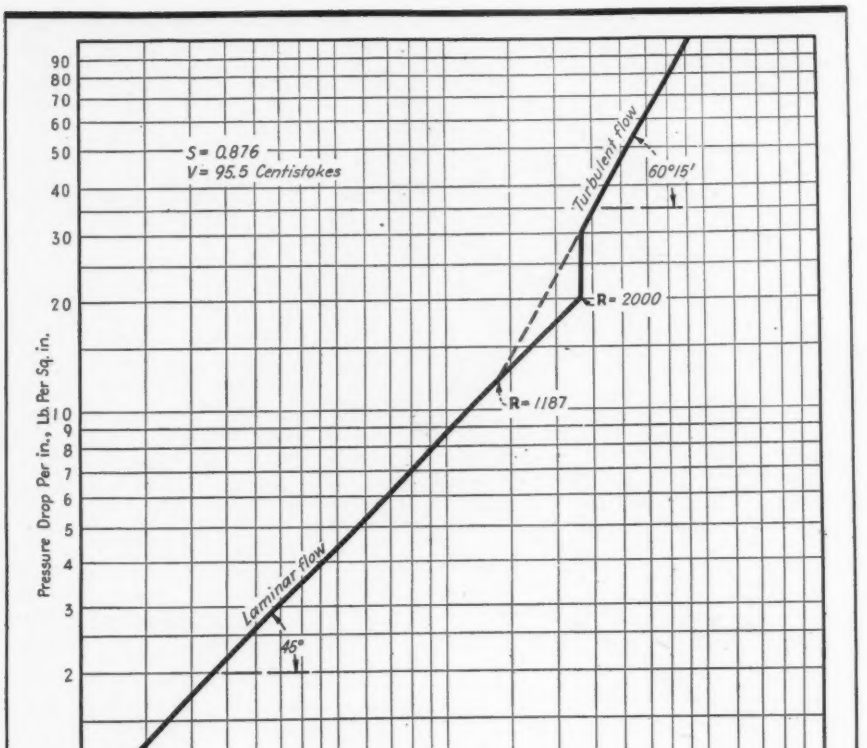


Fig. 1—Pressure drop versus rate of flow for AN-VV-0-366 fluid through a ½ × 0.058 in. tube at 0 deg. F. Turbulent flow is assumed to begin at R equal to 1,187.

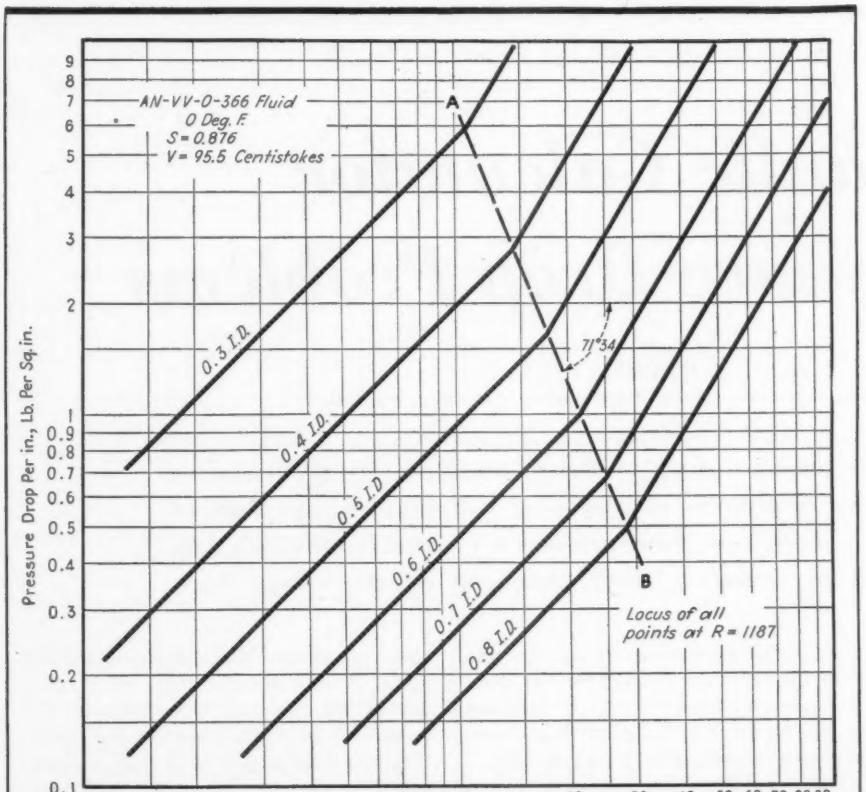


Fig. 2—Family of pressure drop versus flow curves for several tubing sizes.

pressure drop versus rate of flow, it consists of a curve scribed on a transparent sheet which is superimposed on a logarithmic grid. Location of the curve on the grid is controlled by guides which are graduated with scales for temperature and diameter.

The calculator can be adapted for use with a single fluid or constructed so that pressure drop problems involving any liquid can be solved. Tubing sizes ranging from three inches to less than one-eighth of an inch in diameter, fluid temperatures ranging from 160 to minus 70 deg. F., and rates of flow ranging from 0.001 to 1,000 g.p.m. are covered by the calculator developed by Consolidated-Vultee Aircraft for use in the design of its aircraft hydraulic systems. The same principles can be used to make a calculator of any diameter or for any temperature variables.

Proving the calculator involved interpretation of formulas. The problem of pressure drop in hydraulics is no more to be feared than its electrical analogy, voltage drop, which is beautiful in the simplicity of its composite variables. Electrical "fluid pressure drop" is equal merely to the product of current and resistance, the latter for all practical purposes being a constant for any given conduit. In a fluid conduit, it is not convenient to refer to "resistance," since the resistance of a conduit is a function of the "current" or "rate of flow" variable and cannot be treated as a constant. Pressure drop is proportional to rate of flow only when the inertia force of the fluid is less than approximately 2,000 times its viscous force. This ratio is called Reynolds number and is defined in common units

R = Reynolds number
F = rate of flow, g.p.m.
V = kinematic viscosity, centistokes
D = inside dia. of conduit, in.

$$R = 3{,}159\,F/VD \qquad (1)$$

At higher ratios the fluid flow ceases to be laminar in character and becomes turbulent. To date, all formulas describing pressure drop in the turbulent range are empirical.
Where

P = pressure drop per in. of length, lb. per sq. in.
F = rate of flow, g.p.m.
S = specific gravity
D = inside diameter of conduit, in.
f = friction factor

the general formula for pressure drop is

$$P = 0.00112\,F^2\,S\,f/D^5 \qquad (2)$$

The friction factor f is a function of Reynolds number but the function is different depending on whether the flow is laminar or turbulent.

In the laminar flow region the friction factor for smooth conduit is

$$f = 64/R \qquad (3)$$

For values of R in the turbulent range

not exceeding 100,000, Blasius' empirical formula for f shows excellent agreement with experimental data and has the additional advantage of being a straight line on a logarithmic plot

$$f = 0.3164/R^{0.25} \quad (4)$$

More accurate in the higher Reynolds numbers, though more difficult to plot, is the von Karman-Nikuradse expression

$$f = 0.0032 + \frac{0.221}{R^{0.237}} \quad (5)$$

Substituting Equations (1) and (3) in Equation (2) and simplifying, the pressure drop formula for the laminar flow becomes

$$P = 2.269 \times 10^{-5} \times S\,V\,F/D^4 \quad (6)$$

Substituting Equations (1) and (4) in Equation (2) and simplifying, the pressure drop formula for the turbulent flow range becomes

$$P = 4.727 \times 10^{-5} \times S\,V^{0.25}F^{1.75}/D^{4.75} \quad (7)$$

A typical plot of pressure drop versus rate of flow based on Equations (6) and (7) is shown in Fig. 1. Although the laminar flow portion of the curve extends to a Reynolds number of 2,000 before turbulence sets in, it is convenient to ignore the jog and assume that turbulent flow begins where R equals 1,187, at the intersection of the extrapolated curves.

The slope of the laminar flow portion of the curve of Fig. 1 is obtained by differentiation of Equation (6) expressed in logarithmic form, with respect to log F,

$$\frac{d\log P}{d\log F} = \frac{d}{d\log F}\left(\log 2.269 \times 10^{-5}\frac{SV}{D^4} + \log F\right) \quad (8)$$

Since S, V and D are constants, the first term in parentheses drops out and

$$\frac{d\log P}{d\log F} = 1 \quad (9)$$

Therefore, $\tan^{-1} 1$, or 45 deg., is the slope of the laminar flow curve.

Similarly, the slope of the turbulent flow portion of the curve is the differential with respect to log F of Equation (7) expressed in logarithmic form,

$$\frac{d\log P}{d\log F} = \frac{d}{d\log F}\left(\log 4.727 \times 10^{-5}\frac{SV^{0.25}}{D^{4.75}} + 1.75\log F\right) \quad (10)$$

Since S, V and D are constants, the first term in parentheses drops out and

$$\frac{d\log P}{d\log F} = 1.75 \quad (11)$$

Therefore $\tan^{-1} 1.75$, or 60 deg. 15 min. is the slope of the turbulent flow curve.

Regardless of the values selected for specific gravity, viscosity, and diameter, Equations (9) and (11) indicate that the laminar flow portion of the curve will have a 45 deg. slope and the turbulent flow portion of the curve will have a slope equal to 60 deg. 15 min. This gives a clue to the form which a calculator may take. A single curve having these combined slopes, if properly located on a log log graph, will describe the pressure-flow relationship of any given conduit passing any given fluid at any given temperature.

The next step is to investigate the manner in which the individual dimensions of viscosity, specific gravity and diameter affect the location of this curve on the chart.

A family of pressure drop versus flow curves for several tube sizes is shown in Fig. 2. The intersections of the laminar and turbulent flow portions in each curve at R equal to 1,187 lie in the apparently straight line AB. If line AB is truly straight, then the differential of the log of P with respect to the log of F will equal a constant at R equal to 1,187 for any given value of viscosity and specific gravity.

For a given Reynolds number and constant viscosity, Equation (1) indicates the diameter is proportional to the rate of flow. Therefore, substituting F for D, letting K equal the product of the constants and simplifying, Equation (6) becomes

$$P = K/F^3 \quad (12)$$

Differentiating the log of P with respect to the log of F

$$\frac{d\log P}{d\log F} = \frac{d}{d\log F}\left(\log K - 3\log F\right) \quad (13$$

$$\frac{d\log P}{d\log F} = -3 \quad (14)$$

The slope of the diameter locus AB is therefore $\tan^{-3}$ —3, or —71 deg. 34 minutes.

Thus, if the curve of Fig. 1 were transposed along an axis having a slope of —71 deg. 34 min., it would represent the family of PF curves having the same specific gravity and viscosity and varying diameters.

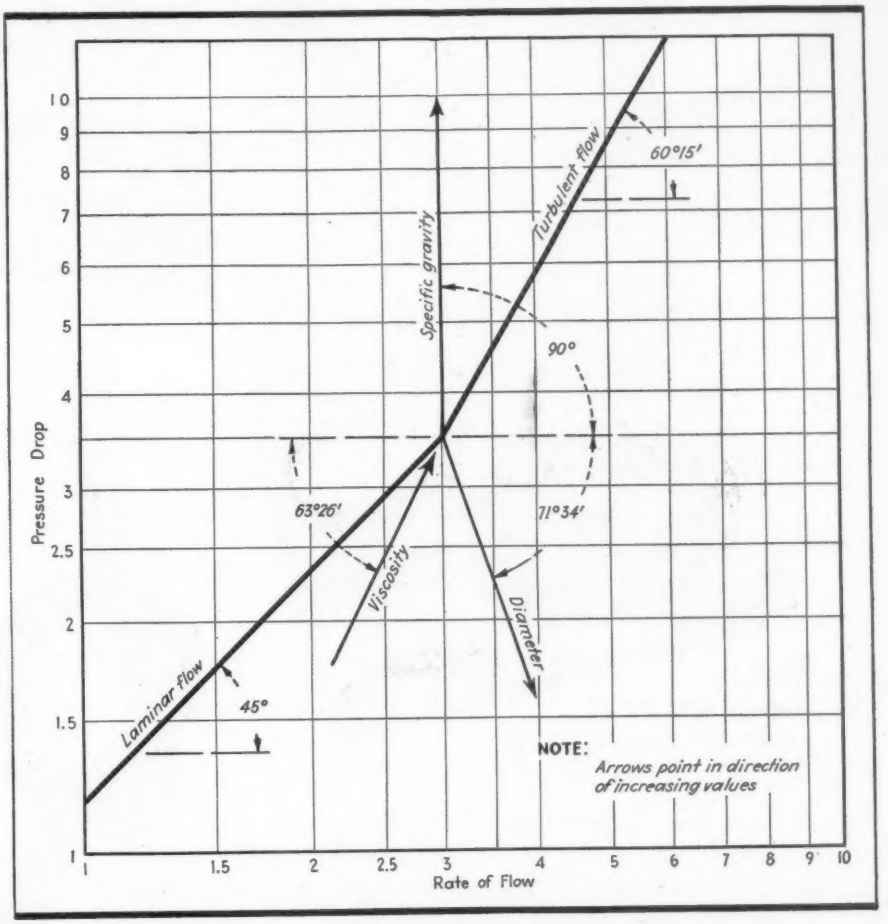


Fig. 3.—Method of applying directions of transposition of pressure drop flow curves.

By similar analyses the directions of transposition of the PF curve for variations in specific gravity and viscosity can be determined. Fig. 3 is a summation of these data.

Sufficient information is now available for the construction of a pressure-drop calculator. Fig. 4 is a schematic representation of one method by which the desired results can be obtained. On the back of a transparent plastic sheet D

(Continued on page 322 of Advertising Section)

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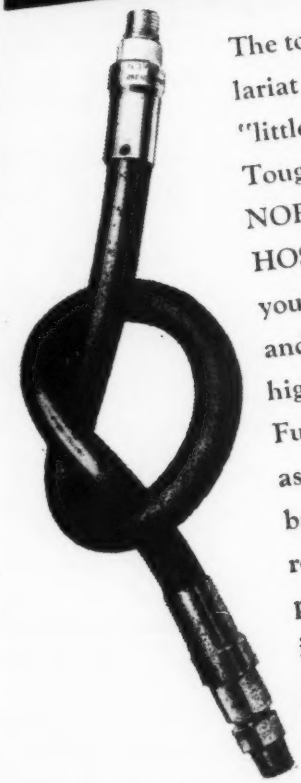

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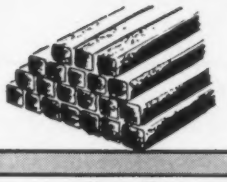

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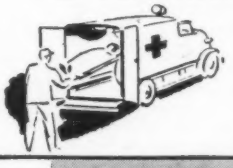

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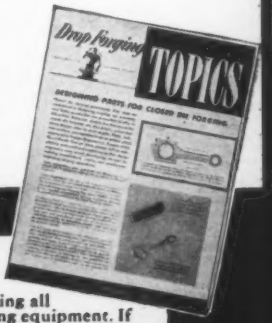

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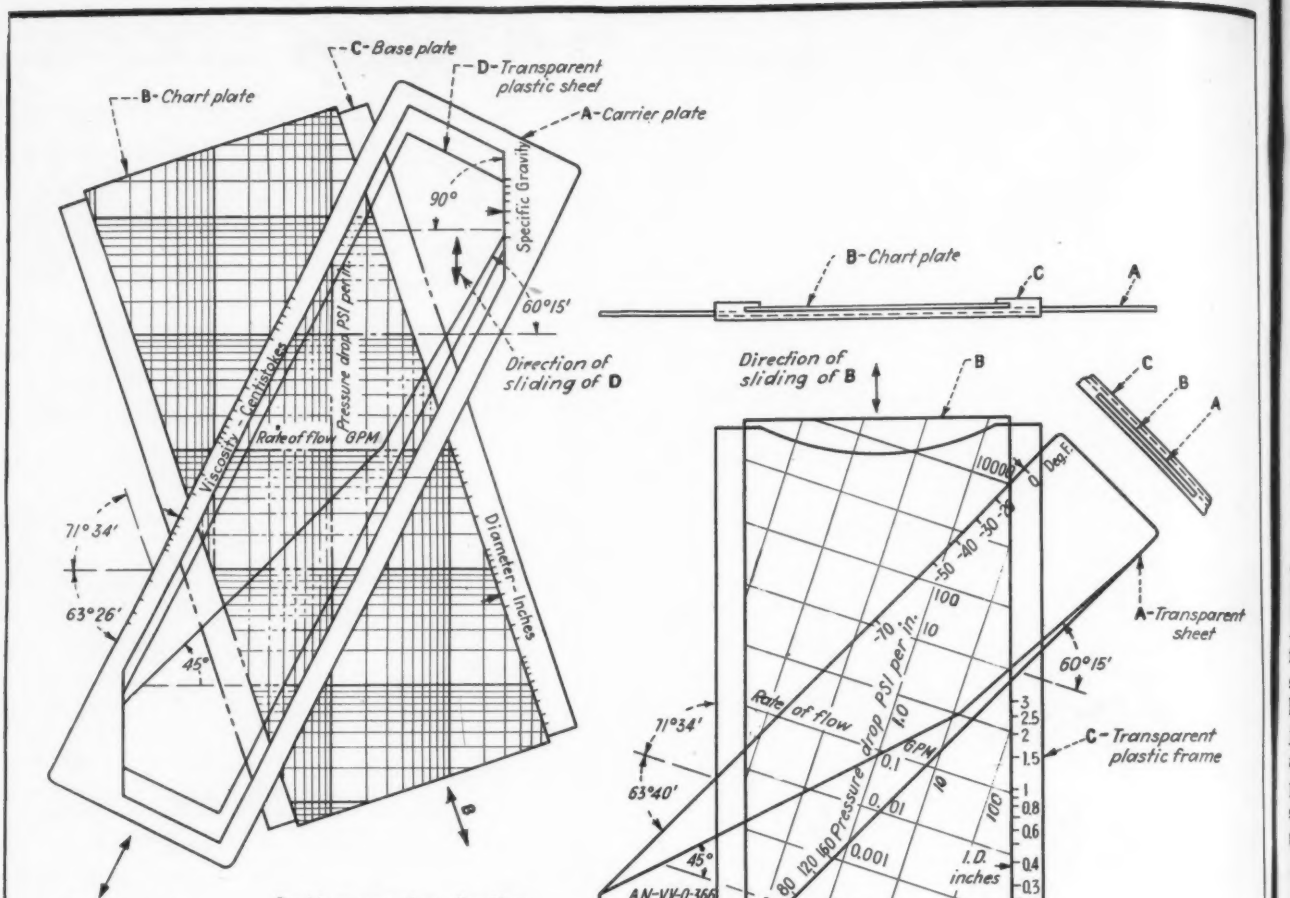

Fig. 4—Schematic representation of the construction and operation of the pressure drop calculator.

Fig. 5—Construction and operation of the simplified form of the pressure drop calculator.

is etched a line having the slope of the *PF* curve. Sheet *D* slides in a groove cut in the carrier plate *A*. An index mark on *D* lines up with a specific gravity scale on *A*. The carrier plate *A* moves in guides on the base plate *C*. An index mark on *C* lines up with a viscosity scale on *A*. *B* is a plate on which is printed a logarithmic chart graduated in pressure drop and rate of flow is indicated. *B* slides in a groove cut in the base plate *C*. An index mark on *B* lines up with a scale on *C* graduated for diameter.

If the *PF* curve is extended to very high Reynolds numbers, greater accuracy can be obtained through the use of a turbulent flow curve corresponding to Equation (5) which gives the von Karman-Nikuradse relationship.

If the calculator is to be used for only one fluid, it will be found far more convenient to combine the viscosity and specific gravity scales into a single scale graduated in temperature. Theoretically, the new scale may not be a straight line, but the error involved in assuming that it is a straight line is negligible. The temperature scale will have a slope very nearly equal to that of the viscosity scale.

The average slope of the temperature scale for any given fluid may be determined from

$$\text{Temperature slope} = \tan^{-1}\left(2 + \frac{\log S_1 - \log S_2}{\log V_1 - \log V_2}\right) \quad (15)$$

where S_1 and V_1 are values of specific gravity and viscosity at a low temperature and S_2 and V_2 are corresponding values at a high temperature. In the case of AN-VV-O-336 hydraulic fluid this angle is 63 deg. 40 min., only slightly different from the viscosity slope of 63 deg. 26 minutes.

The simplified form of the pressure drop calculator is shown in Fig. 5. Transparent sheet *A* carries the *PF* curve etched on its lower surface. Sheet *A* slides in a slot in the transparent plastic frame *C*. An index line on *C* lines up with the temperature scale on *A*. *B* is a plate on which is printed a logarithmic chart graduated in pressure drop and rate of flow as indicated. *B* slides in a groove in the frame *C*. An index mark on *B* lines up with a scale on *C*, which is graduated for diameter.

Included in the many advantages that these calculators offer over the grid charts and momographs previously used are:

1. No auxiliary straight edges are required—no pencil marks on the chart.
2. Very rapid determination of either pressure drop, rate of flow, tube size, temperature, viscosity or specific gravity for any set of conditions.
3. Only three scale settings (two with the simplified calculator) are required to obtain a pressure drop versus flow curve for any set of conditions.
4. Flow condition—laminar or turbulent—is readily apparent.

Bearing Design Simplified By Use of Clearance Ratios

L. M. TICHVINSKY
Senior Mechanical Engineer
U.S. Naval Engineering Experiment Station

Bearing clearance data for various types of rotating machinery. Lower and upper clearance limits are indicated with their effect on the journal bearing performance involving the coefficient of friction and minimum oil film thickness. Also a method for measuring the bearing clearance.

LOADED BEARINGS cannot operate without a wedge-shaped clearance filled with a lubricating fluid. This is true for plane bearings such as a thrust bearing shoe of Kingsbury type, and also for bearings of the journal type. Wedge-shaped clearances and pressure distribution diagrams for plane and for journal bearings are schematically shown in Fig. 1, for clarity the wedge is considerably enlarged.

The symbols used in Fig. 1 are

- p = pressure on elemental area of oil film, lb. per sq. in.
- μ = viscosity of lubricant, lb. sec. per sq. in.
- U = tangential velocity of slider or journal, in. per sec.
- h = oil film thickness at elemental area, in.
- θ = angle spanning the active length of oil film, radians
- r = journal radius, in.
- D = bearing dia., in.
- W = load, in.

Pressure variation over the oil film in the wedge of a plane and of a journal bearing (see "Theory of Lubrication," M. D. Hersey) is plotted in terms of the viscosity μ, speed U and the oil film thickness h from

$$\frac{dp}{dx} \text{ or } \frac{dp}{rd\theta} = 6\mu U\left(\frac{h_{max.} - h_{min.}}{h^2}\right)$$

in which

- dp = pressure increment at any elemental radial section of the oil film
- dx = length of elemental section at slider of oil film
- $rd\theta$ = length of elemental section at journal of oil film

The hydrodynamical theory of lubrication indicates, and is confirmed by simple experiments, that without a wedge-shaped clearance, that is, when the maximum clearance $h_{max.}$ equals the minimum clearance $h_{min.}$, the bearing has no carrying capacity and the oil film collapses. Thus the bearing operation is directly dependent on the physical dimensions of the wedge-shaped clearance. One might easily visualize this by assuming a very large and a very small clearance. In the former the bearing operation is unstable because of excessive play and in the latter the operation of the bearing is restrained because of high friction and temperature conditions.

A study of bearing clearances indicates that there is a wide divergence in practice (see Kent's Mechanical Engineer's Handbook, Vol. III, 1938. Bearings and Lubricants, Section 13-33). The design engineer should know the limits of bearing clearances while the bearing is being laid out on the drafting board. The maintenance engineer should know the limits of the bearing clearance when the bearing is in operation and when the clearance may increase because of unavoidable wear and tear.

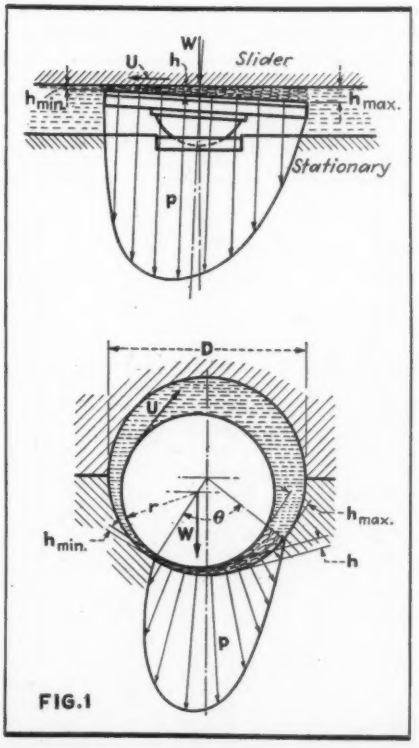

Fig. 1—Wedge-shaped oil film and curve of pressure distribution in a plane thrust bearing and in a journal bearing.

The clearance ratio is a convenient basis to use when determining correct bearing dimensions. The clearance ratio of a bearing is the ratio of the total clearance to the journal diameter. (The radial clearance ratio which is the ratio of the radial clearance to the journal radius is evidently equal to the diametral clearance ratio.) Often the clearance ratio for different types of machinery is specified or chosen from previous experience; then to obtain the diameter of the bearing it is only necessary to multiply one plus the clearance ratio by the journal diameter.

$D = 2R$ = bearing diameter, in.
$d = 2r$ = journal diameter, in.
$D - d$ = total clearance, in.
$R - r$ = radial clearance, in.
m = clearance ratio, in per in.
$= (D - d)/d = (R - r)/r$
$D = d(1 + m)$

Small clearance ratios are used generally for bearings such as the precision type and for accurately machined bearings which operate under perfect fluid-film lubrication with forced-feed oil supply. For bearings which operate under semi-fluid (boundary) lubrication the clearance ratio is not clearly defined because of larger permissible clearance limits.

In bearing design, clearance ratios range between values slightly less than 0.001 and slightly more than 0.002 in. per in. Low clearance ratios are used in machinery bearings such as diesel engine connecting rod bearings, some power transmission units of the gear and pinion type, and in machinery where radial play should be maintained as small as possible. Large clearance ratios are used for bearings in steam turbines, electrical motors and generators and in many high-speed rotating machines. The

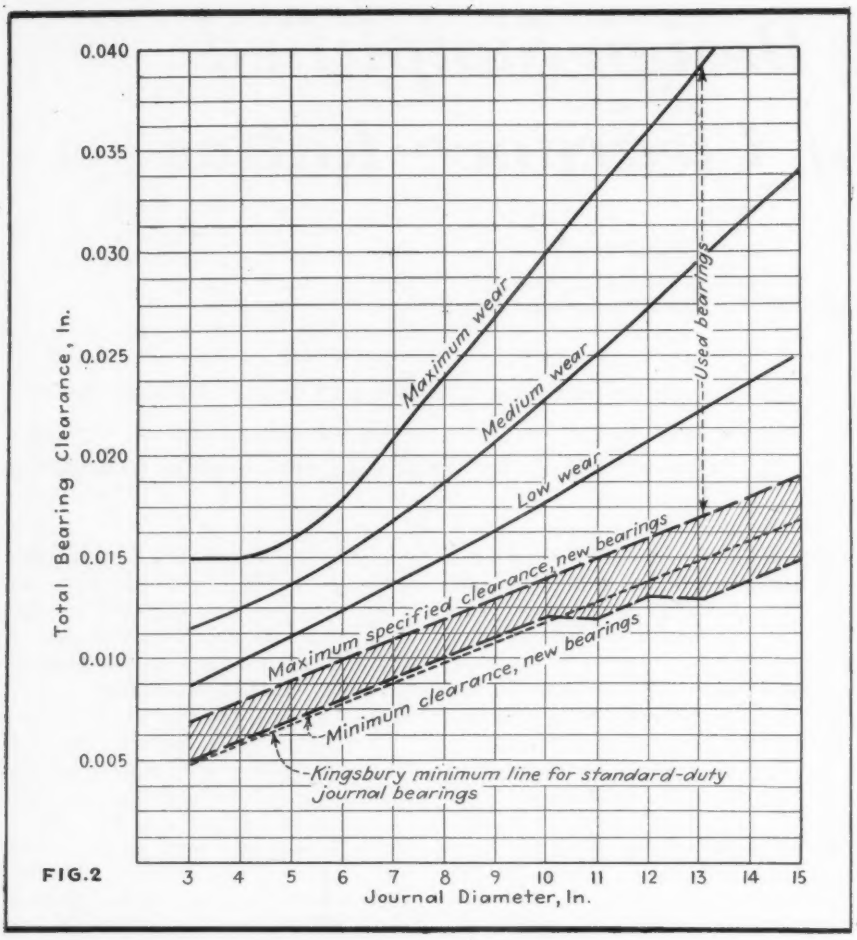

Fig. 2—Limits of bearing clearances for turbine, gear, motor and generator bearings.

standard bearing clearances, clearance ratios and maximum permissible clearances given in Table I are general practice in the design of turbine, reduction gear, generator and motor bearings having journal diameters ranging from 3 to 30 inches.

Standard bearing clearances for small diameter journals, from 1 to 3 in., for many automotive-type bearings are given by A. Willi, "Handbook on Sleeve Bearings," published by Federal Mogul Corporation. Standard bearing clearances for high-speed rotating machinery with journals ranging from 3 to 15 in. are plotted in graph form in Fig. 2. Data for this graph were obtained from sources listed in the appended references. The region of permissible wear, subdivided into low, medium and maximum regions is also indicated in Fig. 2. The extent of the permissible wear is rather wide and the time of replacement or of rebabbitting the bearing should be considered separately for each application. For example, permissible wear should be smaller for precision-type bearings than for standard bearings. In connecting rod bearings, it should be smaller for 4-cycle than for 2-cycle diesel engines. From the data given in Table I and Fig. 2 it can be noted that the maximum rejection clearance ratios range between 0.002 and 0.0025 in. per inch.

The coefficient of friction and consequently the bearing losses are directly

Table I—Bearing Clearances for High-Speed Rotating Machines

Journal Dia., in.	Standard Clearance, in.		Clearance Ratio in. per in.		Maximum Permissible Wear	
	Min.	Max.	Min.	Max.	Clearance, in.	Clearance Ratio, in. per in.
3	0.005	0.007	0.0017	0.0023	0.015	0.0050
4	0.006	0.008	0.0015	0.0020	0.015	0.0037
5	0.007	0.009	0.0014	0.0018	0.015	0.0030
6	0.008	0.010	0.0013	0.0016	0.018	0.0030
7	0.009	0.011	0.0013	0.0016	0.021	0.0030
8	0.010	0.012	0.0012	0.0015	0.024	0.0030
9	0.011	0.013	0.0012	0.0014	0.027	0.0030
10	0.012	0.014	0.0012	0.0014	0.030	0.0030
11	0.012	0.015	0.0011	0.0013	0.033	0.0030
12	0.013	0.016	0.0011	0.0013	0.036	0.0030
13	0.013	0.017	0.0010	0.0013	0.039	0.0030
14	0.014	0.018	0.0010	0.0013	0.042	0.0030
15	0.015	0.019	0.0010	0.0013	0.045	0.0030
16	0.016	0.020	0.0010	0.0012	0.045	0.0028
17	0.017	0.021	0.0010	0.0012	0.045	0.0026
18	0.018	0.022	0.0010	0.0012	0.045	0.0025
19	0.019	0.023	0.0010	0.0012	0.045	0.0024
20	0.020	0.024	0.0010	0.0012	0.045	0.0022
21	0.021	0.026	0.0010	0.0012	0.045	0.0021
22	0.022	0.027	0.0010	0.0012	0.045	0.0020
23	0.023	0.028	0.0010	0.0012	0.046	0.0020
24	0.024	0.029	0.0010	0.0012	0.048	0.0020
25	0.025	0.030	0.0010	0.0012	0.050	0.0020
26	0.026	0.031	0.0010	0.0012	0.052	0.0020
27	0.027	0.032	0.0010	0.0012	0.054	0.0020
28	0.028	0.033	0.0010	0.0012	0.056	0.0020
29	0.029	0.034	0.0010	0.0012	0.058	0.0020
30	0.030	0.035	0.0010	0.0012	0.060	0.0020

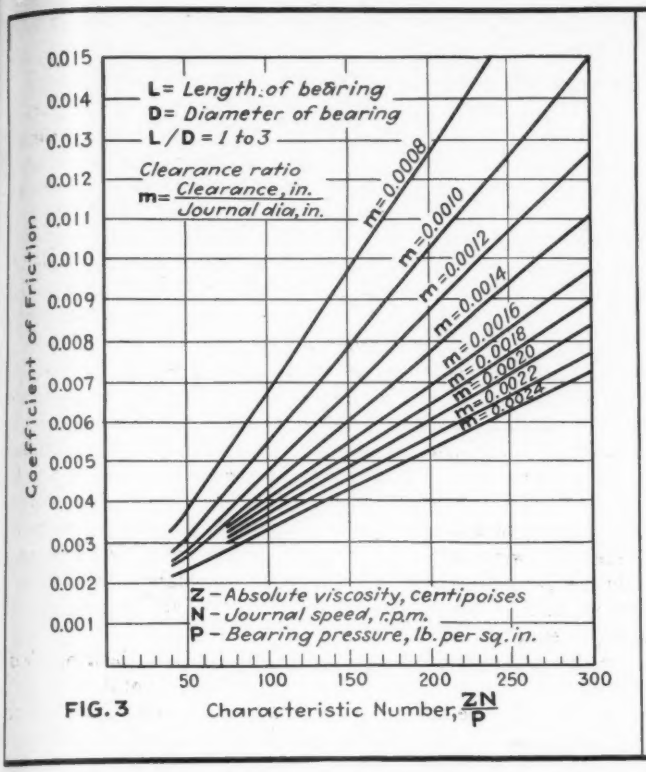

FIG. 3

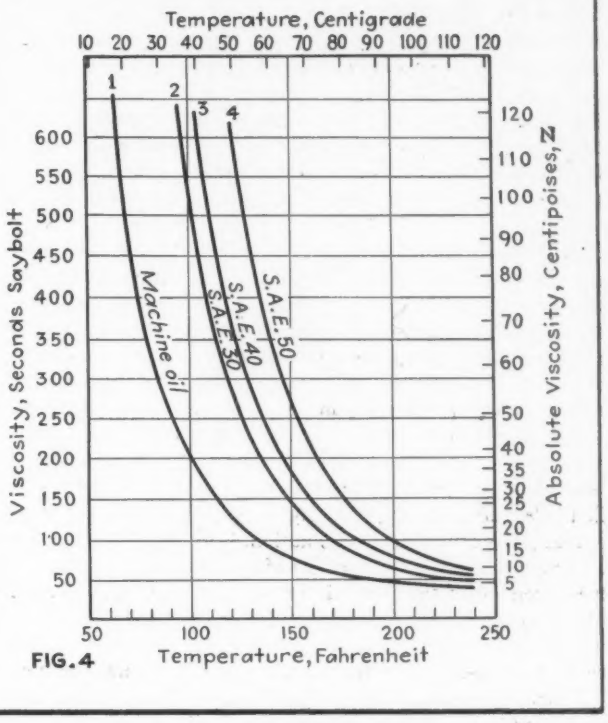

FIG. 4

Fig. 3—Coefficients of friction for several clearance ratios as related to bearing characteristic numbers.
Fig. 4—Viscosity-temperature chart for light machine oil and S.A.E. Nos. 30, 40 and 50 lubricating oils.

affected by bearing clearance. The coefficient of friction increases with decreasing bearing clearance. Coefficients of friction for several values of clearance ratio are given in Fig. 3 in which the coefficient of friction is plotted against the bearing characteristic number ZN/P, where Z is the absolute viscosity of the lubricant in centipoises, N is the journal speed in r.p.m. and P is the pressure on the bearing projected area in lb. per sq. in. The viscosity-temperature chart, Fig. 4, gives the absolute viscosity of a light machine oil and of S.A.E. 30, 40 and 50 lubricating oils.

Performance of journal bearings based on the optimum condition of operation, that is, minimum coefficient of friction at the maximum permissible oil film thickness, has been explicitly described and analyzed by Kingsbury, Howarth and others. In analyzing the characteristics of 90, 120 and 180 deg. clearance bearings (see "Journal Bearing Performance," R. Baudry and L. M. Tichvinsky, *Journal of Applied Mechanics*, December 1935), it was shown that the clearance ratio may vary considerably and still be within the optimum condition of bearing performance.

This observation is important, from practical considerations, because it permits the use of a constant clearance ratio for a rather wide range of bearing operation, ZN/P. In Fig. 5, the radial clearance ratio is plotted against the bearing characteristic number ZN/P for

	Bearing Angle		
	90 Deg.	120 Deg	180 Deg
f	$0.000197\sqrt{\frac{ZN}{P}}$	$0.000200\sqrt{\frac{ZN}{P}}$	$0.000210\sqrt{\frac{ZN}{P}}$
h_{min}	$0.00052r\sqrt{\frac{ZN}{P}}$	$0.00067r\sqrt{\frac{ZN}{P}}$	$0.000097r\sqrt{\frac{ZN}{P}}$

FIG. 5

m – Clearance ratio – – – – – – – – in. per in.
r – Journal radius – – – – – – – – in.
f – Coefficient of friction – – – – – – –
h_{min} – Minimum oil film thickness – in.

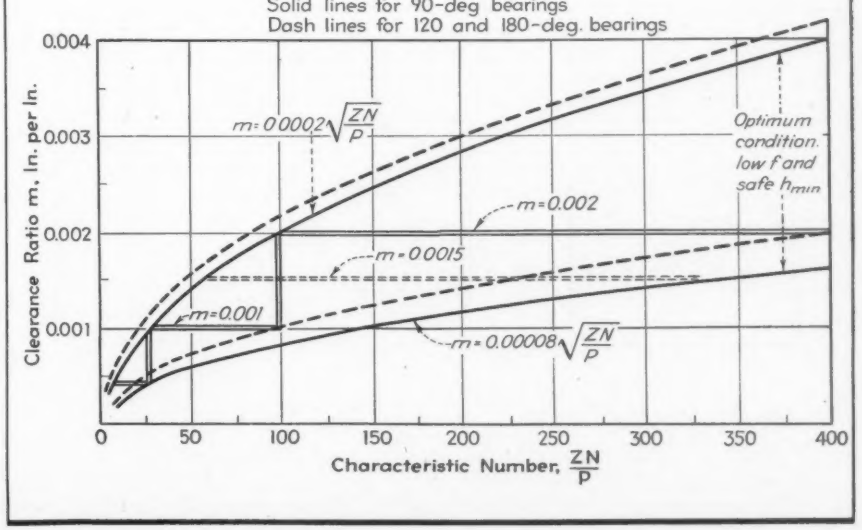

Fig. 5—Clearance ratio for optimum condition of clearance bearing performance.

90, 120 and 180 deg. clearance bearings. This graph was plotted from previously published data which indicated that while the clearance ratio varied from less than 0.001 to more than 0.002 in. per in. the values of the coefficient of friction and of the minimum oil film thickness did not vary more than 3 and 2 percent, respectively from their mean values.

Bearing clearance is usually specified on drawings. Should it be omitted, it can be easily calculated by subtracting the journal diameter from the bearing diameter. By taking the extreme tolerances, two values will be obtained, the minimum and the maximum.

The clearance thus obtained might not be sufficiently accurate because of possible discrepancy between the specified tolerances on the drawing and the actual journal-bearing combination. The best method, naturally, consists of actual measurement of the journal and bearing diameters. It is obvious that such measurements cannot always be made conveniently, especially in the field.

Bearing clearance can be accurately measured in the field by a method called "taking a lead." ("Instructions For the Operation and Maintenance of Bearings and Shafting," United States Navy Department, U.S. Government Printing Office, 1941). This method consists of the following steps:

a. Remove the upper bearing shell and thoroughly wipe the lubricant from the journal and the bearing lining.

b. Lay several lengths of soft lead wire on the journal radially, as shown in Fig. 6. Five pieces are sufficient when the L/D ratios are between 1 and 1½. More wires should be used for larger ratios.

c. Assemble the bearing by replacing the upper bearing shell and tightening the bearing-cap nuts using the specified assembly torques, proceeding exactly as if final assembly were being made. The lead wires thus compressed will assume the profile of the actual total bearing clearance.

d. Remove the upper shell and carefully take out the lead wires for measurements.

When using this method it is essential that all work be done carefully and that particular attention be given to cleanliness. Any foreign matter which might be left in the bearing split will upset accurate measurements. When the leads are removed from the journal it is recommended that one end of each lead wire be pinned to a piece of cardboard, the leads being spaced in the same sequence and at the same intervals as they were on the journal. The examination of the thickness of the lead wires will indicate quantitatively the actual shape of the bearing clearance. If the wire is spread out evenly along its entire length, the clearance is uniform. If it is squeezed out wide in some places and narrow in others, the clearance is irregular, being least at the wide wire section and greatest in the narrow section. Thickness should be measured with a micrometer at several places along the length of the lead so that the clearance at all points can be evaluated.

This method is simple and yields accurate results. Soft lead wires only should be used for such measurement since they will not damage the harder bearing lining; the thickness of the wires should be greater than the total bearing clearance. Lead wires for this purpose should be well protected in storage to preserve the necessary uniformity of diameter.

It should be noted that, as a rule, a bearing clearance ratio between 0.002 and 0.003 in. per in. indicates that the bearing clearance is excessive, and that such bearing should be disassembled and substituted with a bearing which has the clearance originally specified.

Bearings for journal speeds greater than 2,000 ft. per min. are designed with clearance ratios of approximately 0.002 in. per in. Smaller clearance results in high friction (high shearing stresses) and the bearing consequently operates at too high a temperature. It should be mentioned that operation at the lowered oil viscosity, produced by higher temperature, is not sufficient to make up for the increased friction.

High-speed bearings for small diameter journals, such as are used in aircraft where speeds of more than 10,000 and 20,000 r.p.m. are not uncommon, are designed with clearance ratios smaller than 0.0015 in. per in. High-speed bearings must be effectively cooled because at high velocities (high rates of shear) a large amount of heat is generated in the oil film.

When determining the bearing clearance for a particular application it is also necessary to consider factors such as bearing losses, pressures, speed and the viscosity of the lubricating oil. For satisfactory bearing performance the surface finish should be of high quality, journal and bearing deflections should be within allowable low limits, and the bearing should operate at optimum conditions which imply low values of the coefficient of friction at the safe minimum thickness of the oil film.

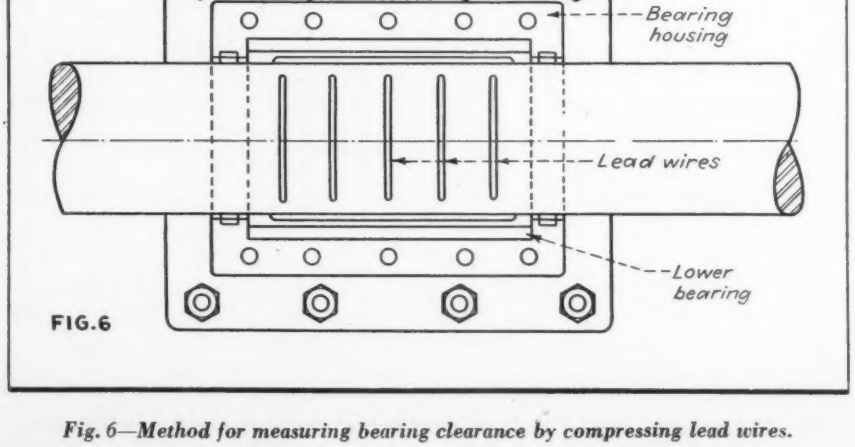

FIG.6

Fig. 6—Method for measuring bearing clearance by compressing lead wires.

REFERENCES

"Instructions for the Operation and Maintenance of Bearings and Shafting," United States Navy Department, U. S. Government Printing Office, Washington, D. C., 1941.

"Optimum Conditions in Journal Bearings," by A. Kingsbury, *Trans. A.S.M.E.*, Vol. 54, 1942, paper RP-54-7, pp. 123-148.

"Graphical Analysis of Journal Bearing Lubrication," by H. A. S. Howarth, *Trans. A.S.M.E.*, Vols. 45, 46, and 47, 1923, 1924 and 1925, respectively.

"Journal Bearing Performance," by R. Baudry and L. M. Tichvinsky, *Journal of Applied Mechanics*," December 1935.

"The Measurement of Attitude and Eccentricity in Complete Clearance Bearings," by D. Clayton and C. Jakeman. The Institution of Mechanical Engineers," London, December 1936.

EDITOR'S NOTE: The opinions or assertions contained in this paper are the author's and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

Lithographic and Electrolytic Reproduction of Templates

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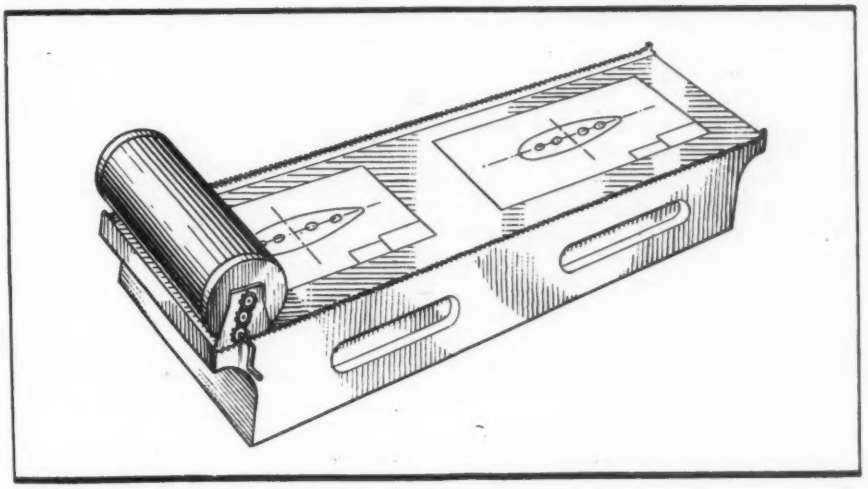
There are several methods for reproducing templates that involve lithographic principles or electrolytic duplication. The most widely used processes are described briefly.

BESIDE the methods previously discussed in this series on template reproduction, there are several other techniques that are suitable for template reproduction work where large volume and extreme accuracy are not requisite. These techniques, lithographic and electrolytic in nature, employ equipment that is simpler and less expensive than the complicated and elaborate equipment necessary for photographic, primary-exposure and after-glow methods of reproduction. The lithographic method can be compared to ordinary lithographic printing practices, and the electrolytic type is similar to reproducing designs by electrolytic etching principles.

The photographic method was reviewed in PRODUCT ENGINEERING, February, 1944, page 130; primary exposure in March, 1944, page 190; and afterglow in April, 1944, page 276.



For offset reproduction a proof press like this is necessary.

Dry-Offset Printing

Perhaps the simplest method of reproducing templates is by dry-offset printing. The only requisite is that the original templates are scribed in a good, finely sanded template lacquer on metal, wood or Masonite. The process consists of inking the original template or scribed layout with a relatively fast-drying printer's ink. The inked template is then placed on a proof-press type machine with a bed long enough to accommodate the template and a sheet of white-lacquered template stock of equal dimensions, both placed end-to-end. A rubber-surfaced roll with a circumference long enough to cover the longest sheet normally used is rolled across the inked template and on across the white painted template stock. The resultant print is black with white lines.

Although it is not practical to attempt the various refinements and special applications handled by some of the more elaborate methods, dry-offset printing is by far the most efficient and productive method to reproduce from existing cut-out templates or from other scribed lines. The accuracy is entirely dependent on the quality of the roll used and the workmanship of the printing bed. The cost of the equipment for this method is about $1,500 for hand-operated machines and up to $14,000 for larger automatic machines.

Curtiss-Wright Corporation has found that up to three sheets of template stock can be laid over registration pins set along the side of the printing area. The templates to be reproduced are then attached to a fourth top sheet by double-backed scotch tape, tooling holes are drilled in the three sheets at once, using the nested templates as masters. The drilled templates are placed in the printing positions on identical registration pins and reproductions are made from the templates taped to the fourth sheet. Accuracy of 0.005 in. over any given area is maintained. Transparencies may be made by this method by printing onto tracing paper instead of metal. The capacity is quite large.

Dry-offset printing would be instituted at step (11) in the general schedule given in the first article of this series (PRODUCT ENGINEERING, January, 1944, page 57) or could be used for duplicating existing templates for tool sub-contractors.

General Lithographic Methods

There has been a process in use in England for some time employing a simple transfer from one inked sheet to a cleaned sheet under pressure. The original is a sheet of aluminum with lines scribed directly into the metal. After the layout is completed, it is surface-etched in a 15 percent caustic soda solution at 70 deg. F. This etched surface is then inked with a printer's brayer and placed in contact with a sheet of white-lacquered template stock in a hydraulic press. The intimate contact afforded by the pressure transfers the image to the lacquered metal and a mirror-image print is obtained.

The press used takes a 24x72-in. sheet and has rubber pads on each platen to compensate for irregularities in the metal. For larger sizes, the press would probably assume huge proportions, but it might be replaced with a 12- or 13-lb. per sq. in. vacuum blanket. This process is inexpensive to operate but is limited

to reproducing from scribed sheets. It would be best instituted at step (11) in the general schedule.

Robinson Litho Method

E. S. and A. Robinson, in England, developed a variation of standard lithographic methods to reproduce lines laid out in the drafting room. The layout is made on metal sheets that have been coated with a colloid in a whirler. A pencil is used to make the drawing and when finished the lines are traced with a sensitizing ink which, under the office lights, hardens the colloid and binds it to the metal base. To insure a good bond the layout is exposed to mercury-vapor lamps for 10 min., the unhardened colloid washed off and the plate subsequently processed by customary lithographic methods.

Transparencies can be made in this manner and the materials upon which reproductions are possible are numerous. No information is available on the cost of the equipment, but a whirler to apply the colloid and lithographic equipment would be the principal items. Reproductions have been made up to 15 ft. long, and this was limited by the whirler available. This method could be used beginning at step (3) or step (11) in the general schedule.

Electrolytic Reproduction

An electrolytic etching method of transferring lines from scribed sheets has been in use for some time at Lockheed Aircraft Corporation, in Burbank, Calif. The original is a sheet of body steel or a galvanized sheet on which has been sprayed a coating of special insulating template paint. Lines are then scribed through the paint to the base metal. The transfer is made to cleaned sheets of body steel, galvanized sheet or aluminum by flooding the scribed surface with a solution of ferrous sulphate, placing the cleaned sheet in contact with it and applying pressure by means of a large press. The press has rubber platens into which are inserted flats of copper. A total current of about 1 kw. hr. is then applied for about 3 sec. The etched copy is washed and dried and a protective clear lacquer is applied.

Many copies can be made from the same original in this way over a period of several months. Accuracy is high because of metal-to-metal contact. The line quality is sometimes inclined to be poor, especially if the template lacquer chips away or if a small amount of oil or grease gets into the scribed line. Mirror image reproductions are the only type available and the materials upon which reproductions may be made are limited to metal. Installation cost is about $5,000. This method is best suited to the duplication of existing templates and would be instituted at step (12) in the general schedule.

Northrop Aircraft, at Hawthorne, Calif., has combined the lithographic and electrolytic principles into a method of electrolytically cutting out the lithographically reproduced template. This eliminates all but a little hand work in finishing the edges of the template. The original is either a template or lines scribed on metal layouts. This original is inked with a printer's brayer, placed on a large proof press and a grained acetate sheet laid over it. A roller exerting a pressure of 1,000 lb. per sq. in. is passed over the two sheets and the ink is thereby transferred to the acetate sheet, giving a negative. The negative is dusted with lampblack to hasten drying and to increase the opacity of the image. The template stock is degreased and pumiced to give a tooth and then sensitized in a whirling centrifuge with a colloid containing a solution of ammonium dichromate. The sheet is dry in about 10 minutes and is ready to be placed in a glass-topped vacuum frame with the negative where it is exposed for 2 min. to arc lights.

After being exposed the sheet is flooded with a "developer" which dissolves the unhardened gelatin in 2 to 3 min., flushed in anhydrous alcohol at 200 deg. F. and inked with etching ink. After drying in a blast of air the face is dusted with an etch-resisting material and the back is coated with this resistant material in liquid form. The sheet is baked for about 10 min. at 500 deg. F. and is then placed in a solution of sodium chloride and electro-etched, using the sheet as the anode and lead as the cathode. Five minutes of etching will give a depth of 0.005 in., at which time the sheet is removed and asphaltum varnish is painted over all the lines except those to be etched through. This is known as "stopping." Replacing the sheet in the etching tank for 40 min. will etch the template free from the surrounding metal.

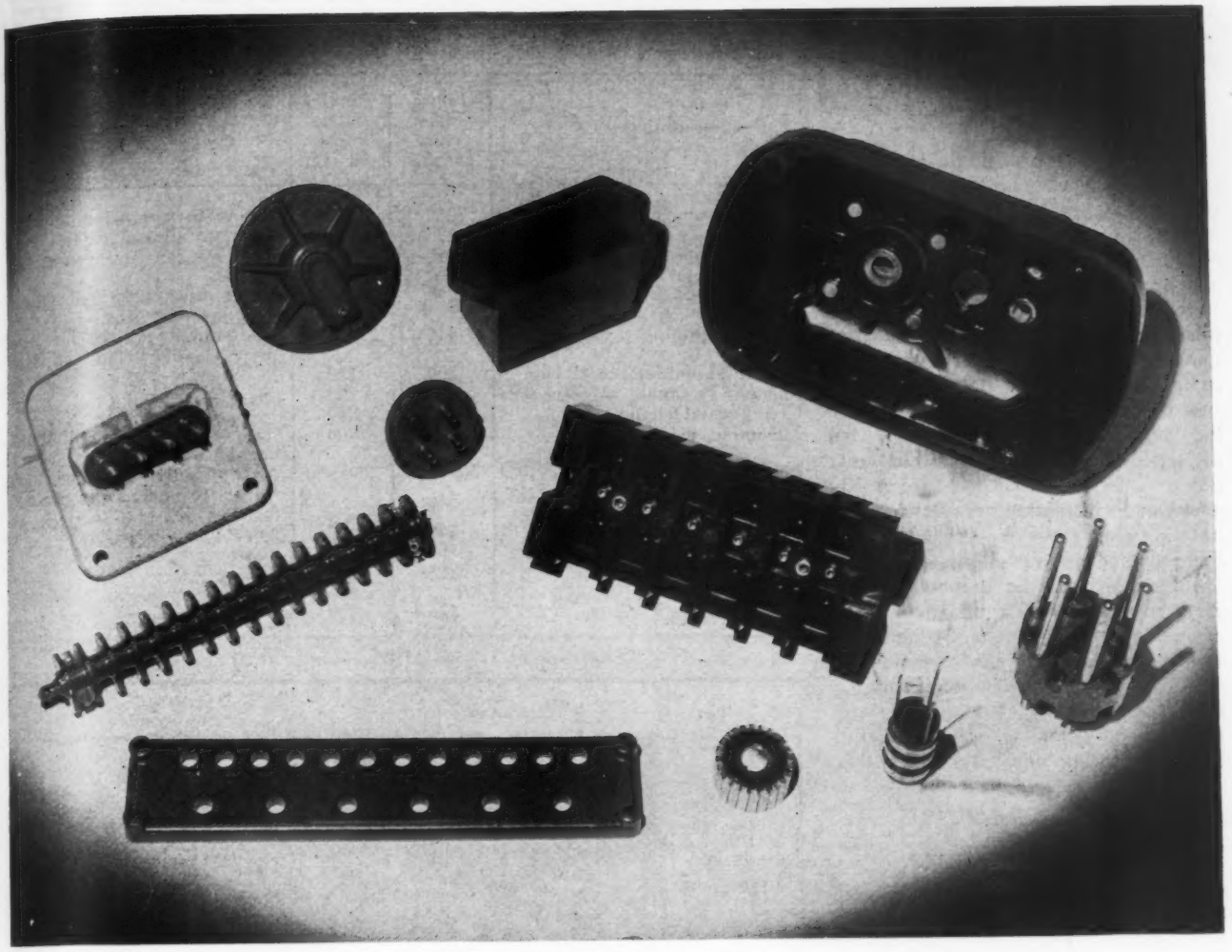
The image stopped by the varnish is very durable and the accuracy of the process is 0.005 in. for any given line. Reproductions can also be made on zinc blocks. Transparencies probably can be made by transferring the image to paper instead of acetate sheet. Ten thousand dollars will install equipment to handle a 4x6-ft. sheet. Since this procedure is principally a shop process it would be best instituted at step (11) in the general schedule.

Nearly all companies mentioned in this series of articles are not limited strictly to any one method of reproducing templates, but employ two or three to gain the maximum advantages. The accompanying chart indicates the degree to which reproductions may be made by any one method from an original or reproductions of any other method. The chart indicates that in some cases reproductions by one method cannot be made from originals of another. In an emergency this can be done by using an intermediate method or excessive time and materials.

Interchangeability of Template-Reproduction Methods

Source of Originals or Reproductions		Efficiency of Use by These Methods: Projection with a Camera	X-Ray Masking Method	X-Ray Pencil or Ink	Phosphorescent Masking Method	Reflectography	Transphoto	Dry-Offset	General Lithographic	Electrolytic	Electro-Etching
Projection with a Camera	Orig.		—	—	—	70	—	100s	100s	60s	100s
	Repro.		100M	100M	100M	70	—	—	—	—	—
X-Ray Masking Method	Orig.	80		100	—	100	—	100	100	—	100
	Repro.	80		90	90M	90	—	—	—	—	—
X-Ray Pencil or Ink	Orig.	80	100		—	70	—	—	—	—	—
	Repro.	80	90		90M	70	—	—	—	—	—
Phosphorescent Masking Method	Orig.	80	100	100		100	—	100	100	—	100
	Repro.	80	90	90		90	—	—	—	—	—
Reflectography	Orig.	80	—	—	—		—	—	—	—	—
	Repro.	50	50M	50M	50M		—	—	—	—	—
Transphoto	Orig.	80	—	—	—	70		100	100	60	100
	Repro.	80	—	—	—	60		—	—	—	—
Dry-Offset	Orig.	80	—	—	—	70	—		100	60	100
	Repro.	80	90M	90M	90M	70	50M		—	—	—
General Lithographic	Orig.	80	—	—	—	70	—	100		—	100
	Repro.	80	90M	90M	90M	70	—	—		—	—
Electrolytic	Orig.	80	—	—	—	70	50M	100	100		100
	Repro.	20	—	—	—	100	50M	—	—		—
Electro-Etching	Orig.	80	—	—	—	70	50M	100	90	60	
	Repro.	80	—	—	—	70	50M	100	90	60	

100 *Indicates perfect reproduction of line quality on original or reproduction*
— *Indicates reproduction not possible or practical*
S *Indicates reproduction possible if original is scribed*
M *Indicates special materials required*



Plastic electrical parts often have metallic inserts that are an integral part of the structure.

Electrical Properties Of Plastics Vary Over Wide Range

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Dielectric strength, dielectric constant, power factor, arc resistance and insulation resistance are covered in this second article of a series dealing with design of plastic parts.

ELECTRICAL conductivity of plastic materials is measured by the resistance which the material offers to the flow of an electric current. A piece of copper wire with a one sq. in. cross-section has a specific resistance of 0.0000017 ohms per cm. of length. Carbon has a specific resistance of 0.004 ohms per cm. and is still classed as a conductor. A material having a specific resistance of 1,000,000 ohms per cm. is on the borderline between a conductor and an insulator. Practically all plastics, with values of 10^{10} to 10^{18} ohms per cm., are above this borderline.

Plastics As Conductors

There are occasions when a plastic application must have positive electrical properties, such as the use of conducting plastics to ground static charges, to provide areas of dissipation and to shield circuits from outside influences. No commonly accepted commercial plastic provides these positive properties, but many of the resins can be modified by the addition of graphite or metallic fillers to serve the purpose. For example, graphite-treated phenol-formaldehyde

fabric-filled compounds show a specific resistance low enough to be sufficiently conductive to ground static charges.

Plastics That Are Insulators

One of the largest single factors in the development and acceptance of plastics has been their good electrical insulating ability. This attribute, coupled with the ease with which parts can be fabricated and molded, has resulted in enormous usage in such applications as relay and tube bases, commutator and collector ring assemblies, switch housings, terminal boards and fuse cutouts. In these uses, the insulating medium is evaluated chiefly by dielectric strength, dielectric constant, power factor, dielectric loss, are resistance and insulation resistance. By knowing values of these properties and their significance the designer can determine which plastic is most suitable for a given electrical application. Since evaluation of many materials under a wide variety of conditions is impossible, it is more important to understand some of the phenomena that take place, and let this understanding aid in judging and anticipating unusual situations.

Dielectric Strength

An electric potential applied across or through an insulating medium attempts to force free electrons from terminal to terminal. The applied potential causes stresses of various types and magnitudes to be set up in the atomic and molecular structure of the insulating material. The degree to which the dielectric can resist these stresses determines its usefulness as an insulator. Air is considered a relatively poor dielectric and will withstand only about 55 volts per mil. Polystyrene, however, will not break down under electrical stress until the applied voltage becomes as high as 5,000 volts per mil of thickness.

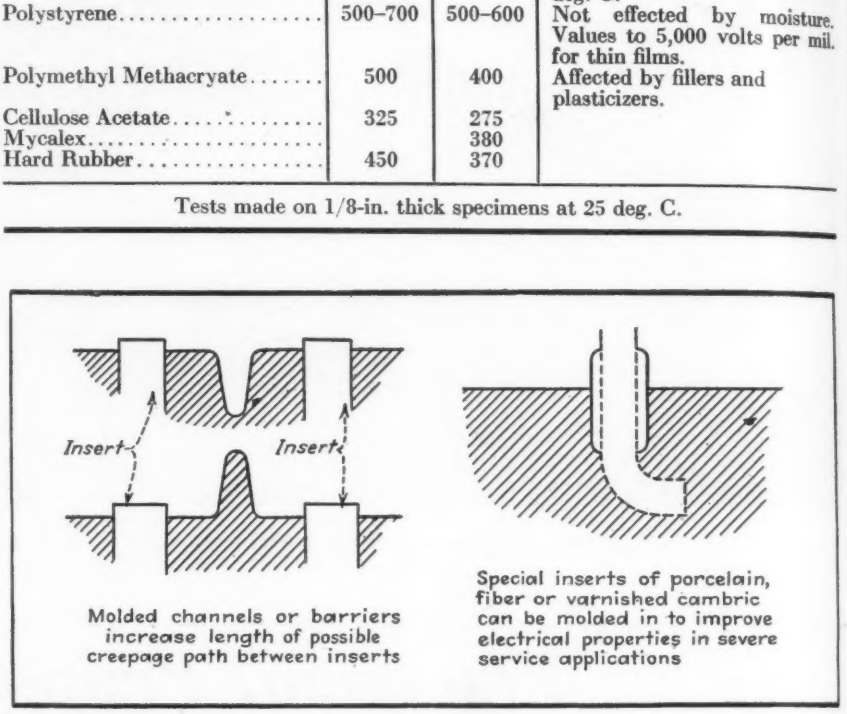
Effect of Water Absorption on Dielectric Strength

Material	Ordinary Test Conditions	After 96 hr. Exposure to Moisture
Phenolic, wood-flour filled	350	100
Phenolic, rag filled	300	100
Phenolic, asbestos filled	125	60
Phenolic-aniline, wood-flour filled	310	135

Dielectric Strength of Plastic Materials Generally Specified for Electrical Parts

Material	Short Time, volts per mil.	Step by Step, volts per mil.	Remarks
Phenolic, general purpose	350	300	Drops to approximately 100 volts per mil. at 100 deg. C.
Phenolic, electrical	350	300	Does not lose strength at 100 deg. C.
Cast Phenolic, electrical	350	300	Other than electrical grades have low strengths.
Phenolic Laminate, paper base	440	300	All laminate values for tests perpendicular to laminations.
Phenolic Laminate, cloth base	300	180	
Phenolic Laminate, asbestos base	100	50	
Urea Formaldehyde	400	350	
Melamine, asbestos filled	350	300	Values drop to one half at 100 deg. C.
Polystyrene	500–700	500–600	Not effected by moisture. Values to 5,000 volts per mil. for thin films.
Polymethyl Methacryate	500	400	Affected by fillers and plasticizers.
Cellulose Acetate	325	275	
Mycalex		380	
Hard Rubber	450	370	

Tests made on 1/8-in. thick specimens at 25 deg. C.



Molded channels or barriers increase length of possible creepage path between inserts

Special inserts of porcelain, fiber or varnished cambric can be molded in to improve electrical properties in severe service applications

Any application that tends to concentrate the electrical stress or weaken or fatigue the dielectric material will cause breakdown at a lower value. Pointed electrodes lower the breakdown value by concentrating the stress. If the plastic is heated, the increased molecular activity tends to weaken the internal forces that resist dielectric breakdown.

High-frequency currents will tend to cause internal heating of the dielectric, which weakens the internal bonds. In addition, the rapid reversal of direction tends to fatigue the material, and breakdowns that are apparently a direct result of fatigue have been noted.

Dielectric strengths at radio frequencies may be as low as 10 percent of 60-cycle test values. Similarly, parts that are under continual electrical strain will break down sooner than if the voltage application is intermittent. If the voltage application is very short, corresponding to a current surge, the breakdown value can be as much as twice that of the standard short-time test. Since water induces ionization, a plastic that has absorbed an appreciable amount of water has lost some dielectric strength.

As shown in the table of dielectric strength of generally specified plastics, this value may drop 70 percent when tested at 100 deg. C. rather than at 25 deg. C. The values given in this table were determined under standard test conditions. Unless the proper adjustments are made between these test conditions and the actual service conditions the values are useless.

Another consideration that the designer must bear in mind is the thickness of the insulation under stress. Standard tests are made and reported on specimens 0.125 in. thick. Tests on films 0.010 in. or less frequently give dielectric strengths up to 5,000 volts per mil.

A.S.T.M. tests specify the manner in

which the load is applied during a test. A "short-time" test uses a voltage increase, usually 1,000 volts per sec., at a constant rate. A "step-by-step" test employs 1-min. applications at evenly spaced voltage steps calculated to break down the material in approximately ten steps.

Dielectric Constant

Dielectric constant is a measure of the effectiveness of a material as an insulator in a condenser. A low dielectric constant material allows very little charge to build up on the metallic plates. A high dielectric constant material draws more charge onto the plates and gives a condenser of higher capacity. Thus, dielectric constant is a quantitative value useful in determining the effectiveness of an insulator. Because the restraining action of the insulator is dependent on the strength of the internal bonds, any external influence tending to weaken these bonds will lower the dielectric constant.

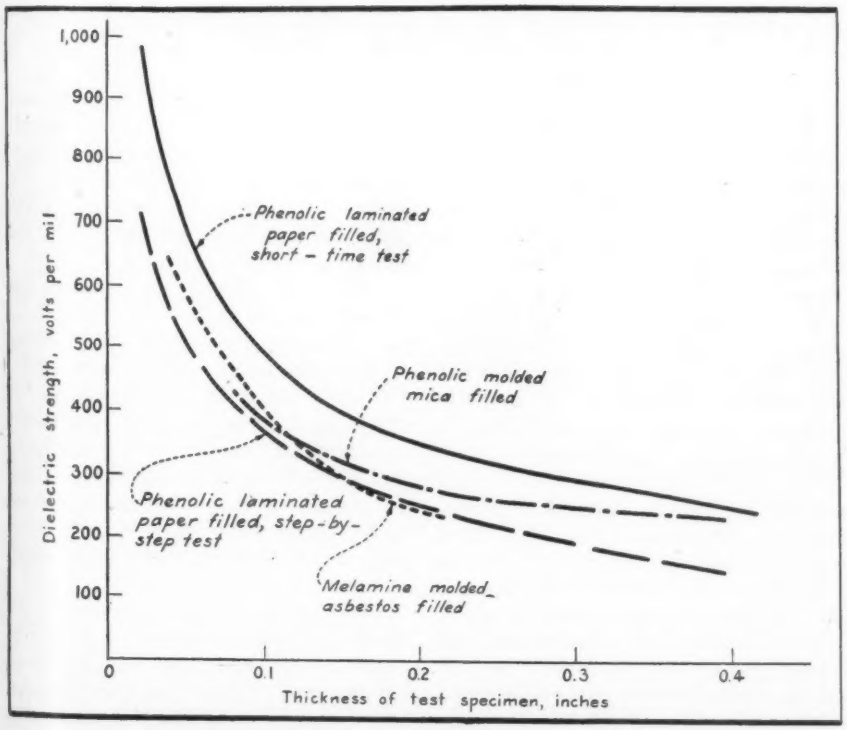
Dielectric constant is generally proportional to the density of a material and the square of its index of refraction. The outstanding exception to this rule is water, which has a dielectric constant of 80. This high value is caused by a di-pole effect. Plastics that exhibit dipole effects have a higher dielectric constant than indicated by their density. Dielectric constant is used in conjunction with dielectric strength to evaluate the effectiveness of a material for use as condenser insulation. Dielectric constant is multiplied by power factor to determine values for dielectric loss.

Dielectric Constant of Plastic Materials Generally Specified for Electrical Parts

Material	60 cycles	1,000 cycles	1,000,000 cycles	Remarks
Phenolic, general purpose	5–12	4–8	4–8	Affected by temperature changes. Much higher values for mineral filled.
Melamine, asbestos filled	7–10	....	7	
Cellulose Acetate	4–7	4–7	3–6	Varies with formulations.
Ethyl Cellulose	3	3	3	
Polystyrene	2.6	2.6	2.6	Non-polar. Stable to frequency.
Polymethyl Methacrylate	3.5	3.2	3	
Mycalex	....	....	8	Withstands 325 deg. C.
Hard Rubber	2.8	3	3.1	
Oiled or Waxed Paper	2–4	....	....	Widely used in condensers.
Mica	4–7.5	....	....	
Air	1	1	1	Basis for comparison.

Power Factor of Plastic Materials Generally Specified for Electrical Parts

Material	60 cycles	1,000 cycles	1,000,000 cycles	Remarks
Phenolic, general purpose	0.2–0.3	....	0.04–0.06	Increases slightly with water absorption.
Phenolic, low loss	0.01–0.02	0.008–0.015	0.007–0.008	Increases with water absorption. Material must be controlled.
Melamine, asbestos filled	0.1	....	0.03	
Polystyrene	0.0002	0.0002	0.0002	Non-polar.
Polyethylene	<0.0005	<0.0005	<0.0005	0.0005 at 10^8 cycles. Low heat resistance.
Polymethyl Methacrylate	0.05	0.05	0.02	High loss at low frequency.
Ethyl Cellulose	0.005–0.015	0.005–0.025	0.007–0.030	
Mycalex	....	....	0.004–0.006	Withstands 325 deg. C.
Hard Rubber	....	....	0.006	



Effect of thickness of test specimen on dielectric strength.

Power Factor

Power factor is an expression of losses resulting from conductance and polarization in dielectric materials. When the frequency is low the loss resulting from conductance is the primary loss. As the frequency is raised, this loss decreases and loss resulting from polarization increases. Most materials, for a given set of conditions, show a minimum loss at some in-between frequency.

Power factor is measured as the ratio of the total power loss (in watts) in the material and the product of the voltage and current impressed upon the material. Much confusion results when this ratio is expressed as a percentage; it should always be used as a ratio.

Polarization losses result from the reversing field of an alternating current. They are important in power and high-frequency applications. Losses result from four types of polarization:

1. Electronic polarization, in which

Arc Resistance of Plastic Materials Generally Specified for Electrical Parts

Material	Arc Resistance	Remarks
Phenolics, general purpose and laminated	Poor	Will carbonize after failure. Performance can be improved by coatings of arc-resistant lacquers.
Phenolics, arc-resistant	Fair	
Urea and melamine	Good	Non-tracking.
Cellulose acetate, methacrylate, polystyrene	Good	Fails by melting.
Hard rubber	Good	
Mycalex	Very good	Non-tracking and high heat resistance.
Cold molded	Very good	
Fiber	Very good	

Standards for arc resistance are approximately 0–50, poor; 50–100, fair; 100–200, good; 200–400, very good.

electrons shift back and forth with the reversals of current.

2. Atomic polarization, in which the whole atom is displaced with the reversal of current.

3. Di-pole polarization, in which the atom is electrically eccentric and, therefore, swings back and forth with the reversing field.

4. Inter-facial polarization between heterogeneous particles in the material. This effect is most important at comparatively low frequencies.

All of these losses result in the heating of the plastic material and in the loss of power in the circuit. Failure will evidence itself by excessive power losses, burned plastics and loss of sensitivity in radio circuits.

By studying the types of polarization contributing to dielectric losses, it is apparent that each type of plastic material will react differently, depending on whether or not it is homogeneous, heterogeneous, polar or non-polar and to what extent each type of polarization contributes to the loss. Thus, at certain frequencies polar plastics become resonant and the loss resulting from this polarization becomes high. Non-polar materials such as polystyrene have low losses, usually resulting from electronic polarization. Heterogeneous materials such as phenolics will have high interfacial polarization at low frequencies. Since water is highly polar, water absorption will increase di-pole polarization. Increase of temperature lowers internal viscosity and tends to increase all types of polarization. Therefore, dielectric losses tend to rise with temperature increases.

Arc Resistance

Arcing across plastics is a rather complex phenomenon. The initial resistance to an arc is determined largely by surface resistivity and fatigue resistance. Once the arc has played across the surface, plastics such as phenolics become carbonized and offer a conducting path for further arcing. Other plastics, such as urea, melamine and thermoplastics, do not carbonize to offer a conducting path after having failed once. Since fatigue lowers arc resistance, standard arc tests have a definite progression of current application with respect to time. The relative resistance is expressed as the number of seconds that the material is under test before breakdown.

Factors which adversely affect arc resistance are those that promote surface conductivity. Pointed electrical contacts, short creepage distances, films of moisture and dust, and high temperature cause early breakdown. Arc resistance of phenolics can be improved by the application of arc-resistant lacquers.

Insulation Resistance

Insulation resistance is determined from the current leaking through the volume and over the surface of an insulation. Its value is calculated to equal that of the resistance of a one-cm. cube and gives the specific resistance, which determines whether a plastic is a conductor or an insulator. Surface resistance is lowered markedly by films of dust or moisture which sometimes account for unexplainable voltage drops. Insulation resistance decreases at high temperatures and with increase of moisture absorption.

EDITOR'S NOTE—The next article in this series on plastics' part design will deal with the mechanical properties of plastic materials.

The Field of Synthetic Rubber Versus Natural Rubber and the Plastics

"We think of plastics as substances that readily permit themselves to be formed or molded into desired shapes and, thereafter, have reasonable stability against deformation," Dr. R. P. Dinsmore, vice-president, Goodyear Tire & Rubber Company, told the fall meeting of the Society of the Plastic Industry. "Rubbers, on the other hand, while plastic when being formed and processed, are, after . . . vulcanization, capable of extensive deformation with more or less complete elastic recovery. . . ."

". . . Successful synthetic rubbers came . . . in the late 20's and early 30's. The Thiokols . . . were between plastics and rubbers. Neoprene . . . and the bunas . . . were the first synthetic rubbers to create real commercial interest.

". . . The requirements [of a true plastic] are ready moldability under pressure (or heat and pressure) and resulting stability of form . . . On the other hand, the requirements for rubber are first that it be plastic while it is being formed and manipulated and second that, in its final form, it be . . . highly extensible and capable of rapid elastic recovery . . . Since this latter requirement negatives . . . plasticity, it presupposes the change of state brought about by vulcanization.

". . . [A plastic] may have one or more of the essential properties of vulcanized rubber or may have all to a lesser degree.

"By selecting a highly elastic rubber on the the one hand and a highly moldable and ultimately highly stable plastic on the other, we may compare the essential properties of any intermediate resin and determine whether it . . . approaches a rubber or plastic . . .

"When we examine the imposing list of plastics with their varied properties we are impressed with the wide utility of this class of materials . . . If we reflect upon the rapidly growing family of synthetic rubbers and realize that vulcanization will serve to link more closely many plastics with the rubbers, we will be obliged to agree that known resins will form a continuous chain of properties from the truly plastic to the truly elastic . . . .

"With such a prospect at hand, one would be foolish indeed to expect a separation of the field of application of plastics and rubbers. The most that can be expected is a substantial separation of the two extremes. . . ."

Catapulted from the deck of a cruiser, a Ranger-powered Curtiss SO3C Seagull roars into action. Performance of this 12-cylinder air-cooled inverted inline engine is increased by the Al-Fin process which improves cooling.

Official U.S. Navy Photo

New Steel-Aluminum Bond Boosts Engine Power

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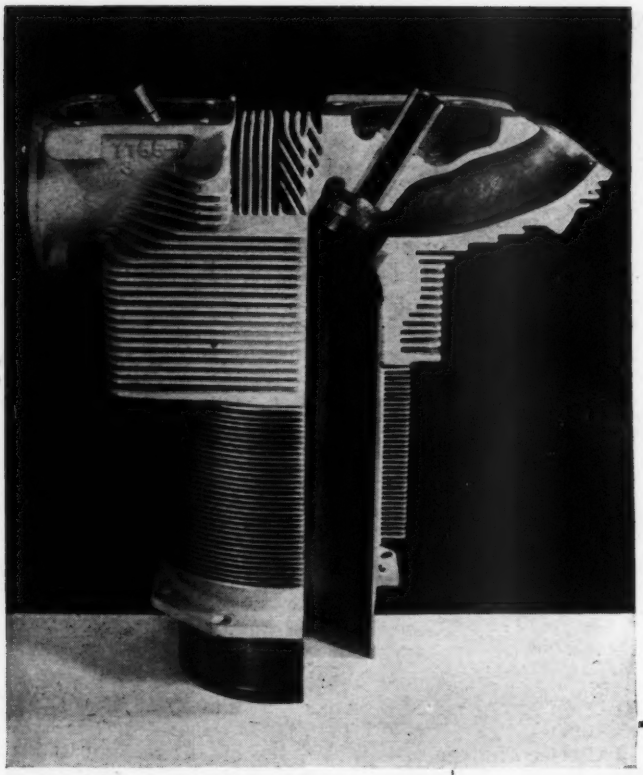
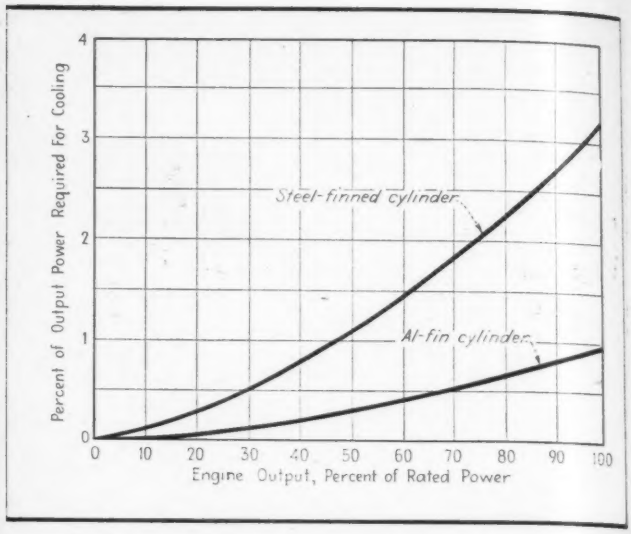
Composite steel and aluminum cylinder barrels, which are used in Ranger aircraft engines to increase power by combining the strength of steel with the rapid heat dissipation of aluminum, show the possibilities of a new method of bonding these two materials together for all kinds of parts—castings, forgings, sheet metal, and others.

A PRACTICAL method of bonding aluminum or aluminum alloys to steel has been developed for production of composite cylinder barrels for Ranger aircraft engines. The process is applicable to castings, forgings, tubing or fabricated parts of steel and other metals. It is primarily a casting operation and is relatively inexpensive from the standpoint of both installation of equipment and production operation. Aluminum sections up to 3 in. in thickness have been used but somewhat heavier sections can be applied, depending on the shapes of both the steel and aluminum members of the composite structure.

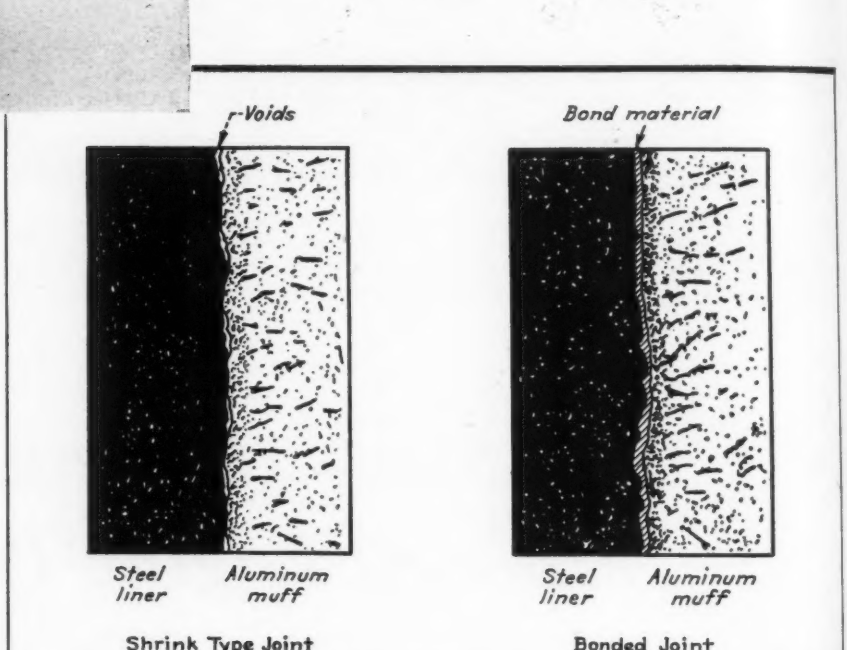
The possibility of bonding aluminum to steel was established earlier by the successful production of aluminized steel sheets. Such sheets have a thin coating of aluminum bonded to the steel. Engineers of the Fairchild Engine and Airplane Corporation visualized the possibility of developing a new technique whereby a heavy, molded coating of aluminum could be fused to steel and



Ranger engine cylinder cut away to show Al-Fin design. Fins on cylinder barrel were machined from solid aluminum cast around the barrel.



Graphic picture of improvement in engine power output obtained by use of Al-Fin cylinders as indicated by reduction in power required for cooling.



Magnified sections of shrink-fit joint and Al-Fin bond between steel cylinder barrel and aluminum muff show improvement in metal continuity for heat conduction.

other metals. To this end a research and experimental program was undertaken by Al-Fin Corporation, a subsidiary. The resulting method is known as the Al-Fin process, being named for its first application, and is available under license by the company.

Bond Properties

The joint between the steel member and the aluminum member consists mainly of an alloy of iron and aluminum. The thickness of the bonding alloy joint ranges from 0.0005 to 0.00075 in. Tensile strengths of approximately 6,000 lb. per sq. in. have been determined on assemblies of steel to pure aluminum. It is believed significant that this value is greater than the yield strength of the pure aluminum alone. Repeated expansion and contraction of the composite steel-aluminum part has no detectable effect on the physical or thermal properties of the bond, as shown by the performance record in all single-cylinder and production engine installations.

Past experiences have shown that nonferrous metal coatings on steel may result in reduced fatigue strength. Hence careful investigation has been made of the fatigue strength of Al-Fin aluminum-steel. Unfortunately, fatigue tests are time-consuming and the nature of the aluminum-steel combination makes it extremely difficult to determine a test method that will give dependable results.

Apparently the values determined by the rotating beam test, which gives fatigue strength for complete stress reversals, are lower than the true values. An aluminum coating 0.005 in. thick was applied by the Al-Fin process to steel. A rotating beam test showed the fatigue strength was 23 percent less than that of the parent steel. For cycling stress in tension only and ranging from zero to maximum tension, the fatigue strength would presumably show a decrease of only about 13.5 percent. This value was arrived at by assuming the same ratio of fatigue strength at complete stress reversal to fatigue strength under repeated tension as determined for similar alloyed coatings by Swanger and France and reported in Vol. 32, *A.S.T.M. Proceedings.*

The first commercial application of the Al-Fin process was in the manufacture of air-cooled engine cylinder barrels. The object was to increase the rate of heat dissipation, which is a major factor affecting efficiency and horse-

power output of the engine. Originally cylinder barrels were made of thick-walled cylindrical steel forgings with closely spaced thin fins machined into the outside walls. The relatively low heat conductivity of steel limited the rate of heat dissipation. A number of methods were then developed to improve cooling.

Cylinder Barrel Development

One of the early developments to obtain improved cylinder barrel cooling was the use of fins machined from a thick copper sleeve bonded to a thin-walled steel cylinder. Such constructions were relatively heavy. Some trouble was experienced from corrosion of the copper. The fins lacked stiffness and mere air pressure could easily bend them out of shape.

It was quite natural that consideration be given to the possibility of aluminum cooling fins. Development of designs of aluminum cylinder heads with cast fins created a wealth of data. Despite the fact that heat conductivity of pure aluminum is not much more than half that of copper, the difference was almost entirely compensated by the lighter weight of aluminum. Its greater stiffness was also a favorable factor.

Since it was not known how to bond aluminum to steel, the logical method for obtaining aluminum fins on a steel barrel was to shrink-fit an aluminum cylinder over the steel one. When this sleeve was pure aluminum, which has higher heat conductivity than its alloys, it was found that its low yield point made it impossible to maintain a strong grip on the steel. The joint loosened from the repeated expansions and contractions. It was necessary therefore to use a sleeve of high-strength aluminum alloy.

Even under the best conditions, the shrink-fitted aluminum sleeve has a relatively inefficient contact with the steel barrel as regards heat transfer. The deficiencies in surface contact are accentuated by the greater rate of thermal expansion of the aluminum. Obviously the optimum design would be one in which a pure aluminum sleeve is bonded to the steel barrel. This is the accomplishment of Al-Fin Corporation. Since maximum heat dissipating capacity requires fins thinner than can be cast, the fins are machined from these aluminum sleeves, as was done on shrink fitted muffs.

Comprehensive tests of a single-cylinder engine with such barrels were conducted over a period of a year and a half. As compared to the same engines with conventional steel-finned cylinder barrels, the Al-Fin aluminum-finned barrels gave the following results:

1. At the same engine horsepower output and same cylinder barrel temperature, the quantity of cooling air was 55 percent, the cooling air pressure drop was 37 percent, and the cooling air horsepower required was 22 percent.

2. For the same cooling air pressure drop across the baffles and the same initial temperature of cooling air, the maximum net horsepower of the Al-Fin barrel engine was double that of the engine with steel fins.

3. At equal horsepower outputs and cooling air horsepower, the average temperature of the Al-Fin barrel was 50 deg. F. lower than that of the steel-finned barrel. Subsequent tests on a standard engine showed the Al-Fin barrel to be 30 deg. F. cooler.

4. After 85 hr. of engine operation at loads ranging from normal to 140 percent normal, the bond between the steel and aluminum was unaffected.

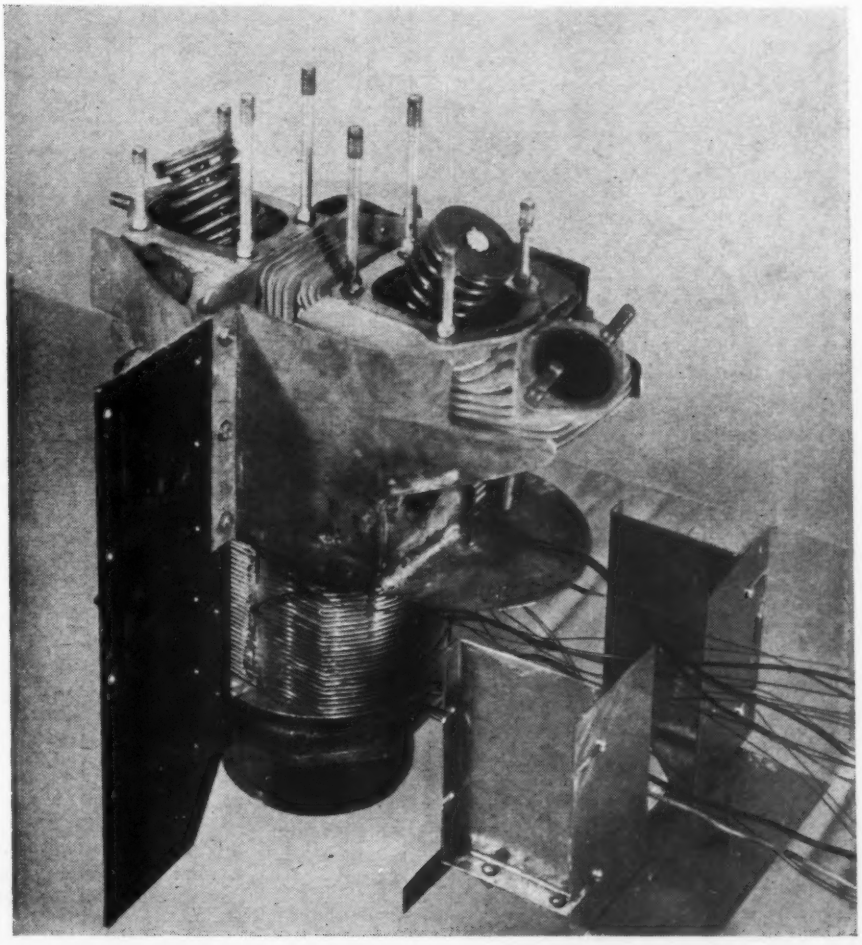
A number of mechanical advantages were also disclosed. No difficulty was encountered in the manufacture of the Al-Fin cylinders with reference to distortion, particularly roundness. This might be explained by the added stiffness contributed by the bonded aluminum, which also serves to damp vibrations. The Al-Fin cylinders cost about 20 percent less than the conventional steel-finned type largely because of the quicker machining of aluminum.

Other Applications

Applications of this method of bonding aluminum to steel are not confined to heat dissipation, important as this application is. It may well prove useful in structural applications where corrosion resistance is required. Vessels for chemical equipment can be lined with aluminum by this process. Such parts as stirring paddles or agitators for chemical or other processes requiring mixing can be aluminum coated. Trays and bubble caps for fractionating towers are possible applications. In many applications where stainless steel has been necessary there is now the possibility of using aluminum-coated carbon steel.

In other applications where improved heat dissipation is desired, as in airplane wheel brakes, heat exchangers, radiators, and the like, it may be practical to employ cast fins.

Since the process is new, applications and possibilities of the process must be based largely upon the method as now used successfully for producing composite parts mentioned in this article.



Test set-up for Ranger engine cylinder with Al-Fin barrel and turbulent flow baffles.

PNEUMATIC CIRCUITS AND TY

CONTINUING FROM LAST MONTH, this series of schematic diagrams illustrates more of the possibilities of pneumatic controls in operation of industrial equipment. Compressed air affords clean, dry, non-hazardous means for automatic or semi-automatic operation of machines or processes with one-way piping. Compressibility of air permits variations of general conditions of operation to suit individual requirements. Combination with electrical devices is often advantageous. These layouts are typical of those developed by Ross Operating Valve Company.

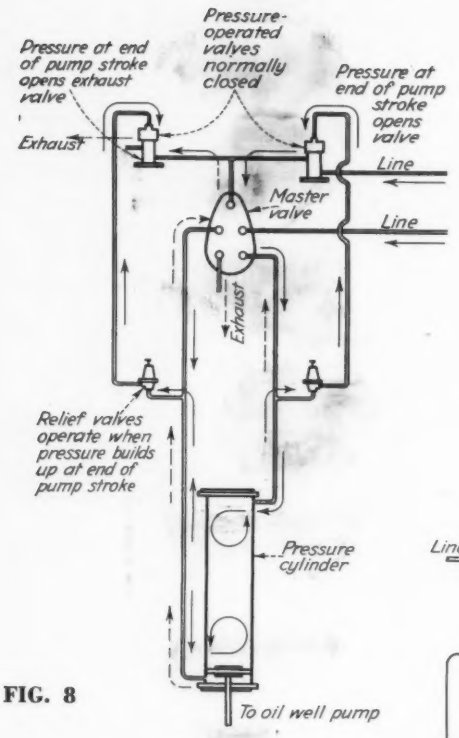

Pressure-operated valves normally closed
Pressure at end of pump stroke opens exhaust valve
Pressure at end of pump stroke opens valve
Exhaust
Line
Master valve
Line
Exhaust
Relief valves operate when pressure builds up at end of pump stroke
Pressure cylinder
To oil well pump

FIG. 8

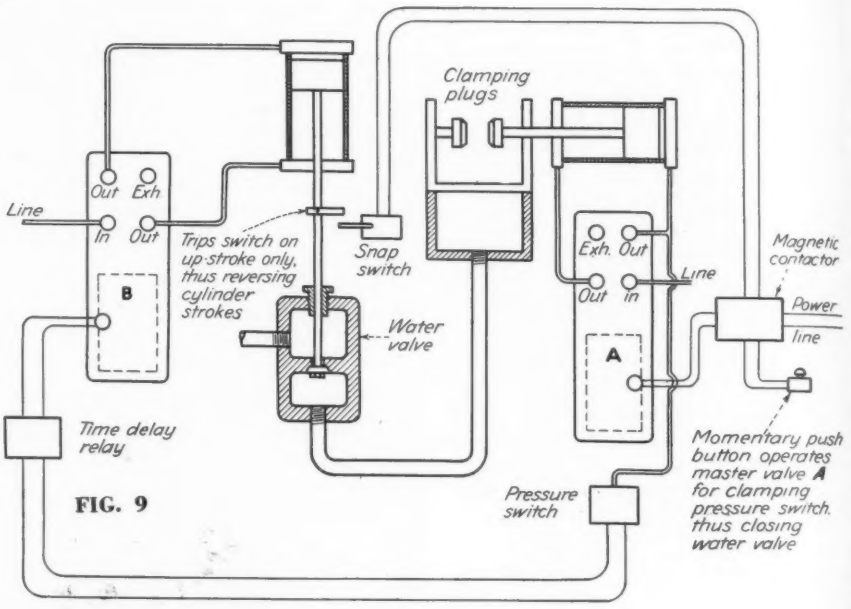


FIG. 9

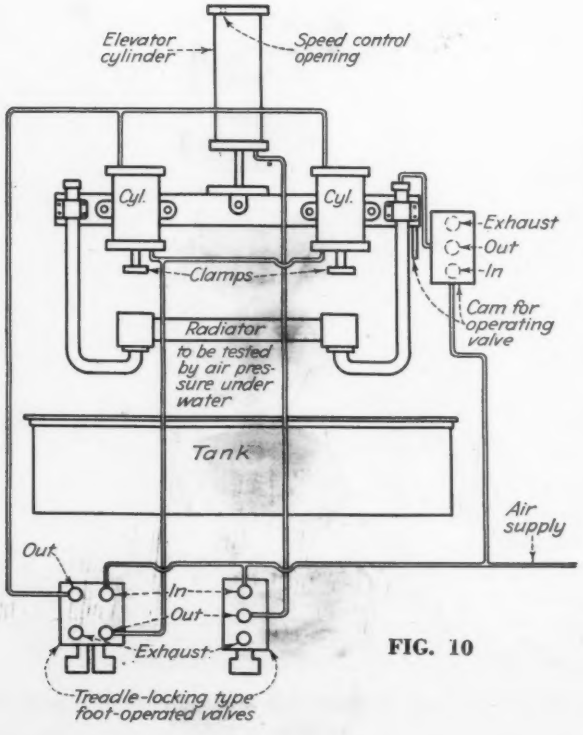


FIG. 10

Fig. 8—Pneumatic system arrangement for automatic reversal of master valve and piston in a pressure cylinder used to operate an oil well pump. Relief valves take air pressure built up at end of stroke, passing it to pressure-operated valves, one of which allows passage of line pressure to the master valve operating piston at one end of the stroke and the other relieving this pressure at the other end of the stroke, thus maintaining continued operation of the pump.

Fig. 9—Treating process involving automatic flow of water by a combination of electric and pneumatic control. Pressure switch, closed by air from valve *A* to clamping plug cylinder, operates valve *B* and closes water valve. Up-stroke of water valve stem opens electric circuit, releases clamping plugs, opens pressure switch, reverses valve *B*, thus opening the water valve.

Fig. 10—Radiator test set-up with foot-operated valves controlling clamps and dipping operation with automatic application of air pressure to radiator under test.

TYPICAL APPLICATIONS—II

Fig. 11—Pneumatic controlled convertor operation. Drop in air pressure to tuyeres opens electric switch, thus closing solenoid-controlled valve and applying line pressure to air motor. Simultaneously Air-flex clutch is operated and the brake released. Converter shaft is turned counter-clockwise until cam-operated valve opens line to air motor. Electric motor is used for returning converter.

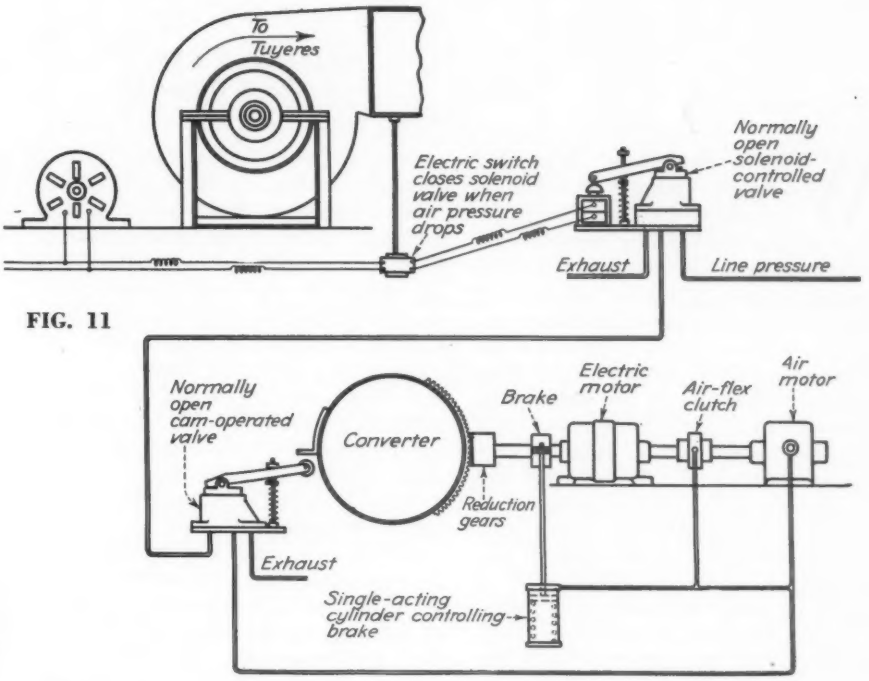


FIG. 11

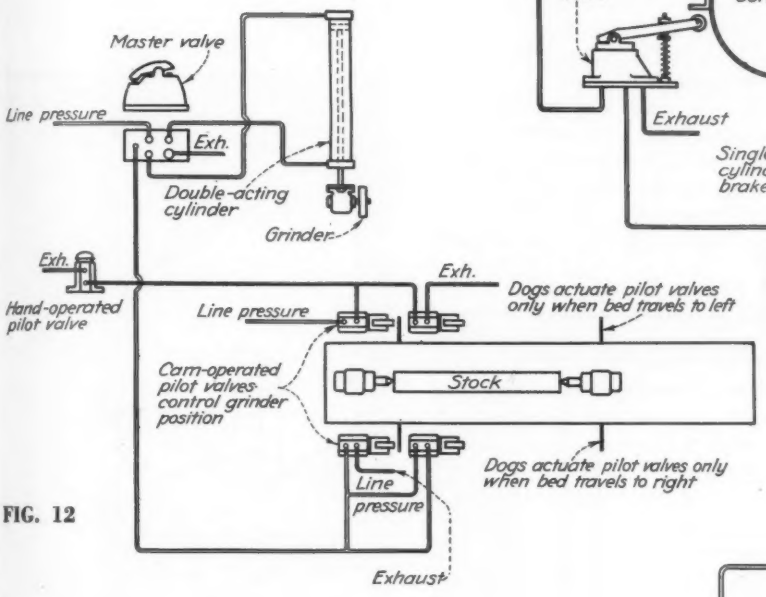


FIG. 12

Fig. 12—Automatic grinding operation with separate controls for right and left travel of the stock. Hand operated pilot-valve permits raising grinder at any time.

Fig. 13—Automatic process is started by manual operation of valve *E*, which clamps work in position by means of master valve No. 1. Manual operation of valves *D* and *D'* starts spray cylinders. Process is stopped by valve *F*, either manually or automatically, which releases clamping cylinder. Up-stroke of clamp opens valve *B* and *A*, reversing spray cylinders and operating the knock-out cylinder by means of master valve No. 3. Valve *C*, opened by knock-out cylinder, reverses No. 3 master valve and returns knock-out cylinder.

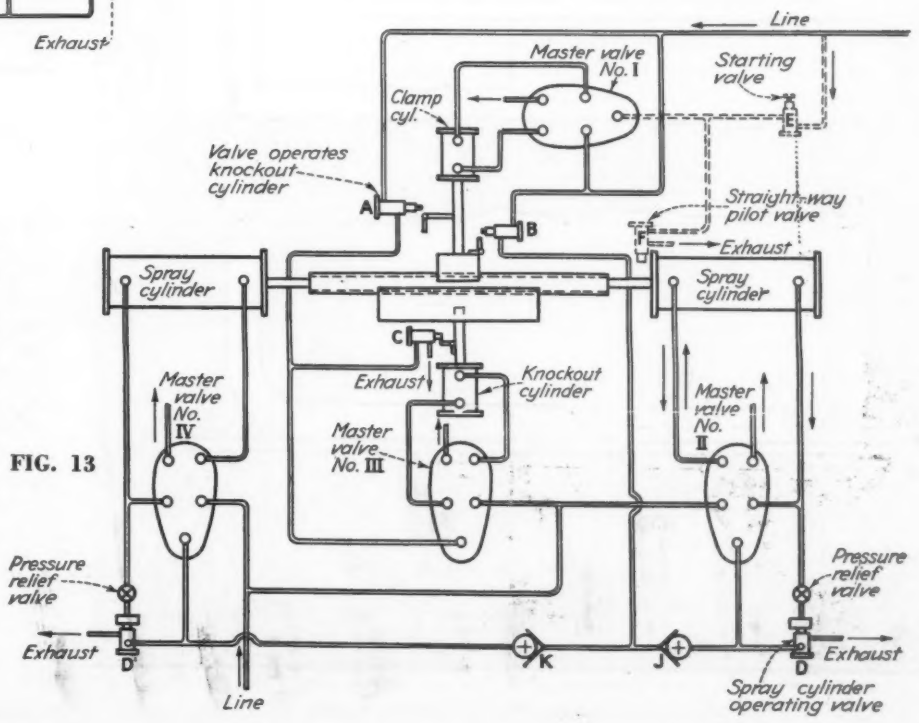


FIG. 13

Designing Joggles For Sheet-Metal Assemblies

FRANK M. MALLETT
Curtiss-Wright Corporation

WHEN sheet-metal assemblies require fitting a member to two parallel surfaces not in the same plane, the forming necessary to make a proper fit is called joggling and the part is said to have a joggle. It is true that a joggle makes a part more expensive, but if it results in better fits the saving in assembly expense more than makes up the increased cost of the part. Experience in aircraft manufacturing shows the biggest item of expense, both in money and time, is in assembly and not fabrication of detailed parts.

Many sheet-metal parts in airplanes are joggled in one or more places. Designing the shape and proportions of joggles in such a way as to keep within forming limitations involves several considerations. If the offset between the two parallel planes is relatively small, nothing is gained by joggling or offsetting the surface to be fitted against them. Some aircraft designers set this minimum at arbitrary figures such as 0.020 in. or 0.030 in. Such allowances are relatively high and in many instances will increase the cost of assembly by a far greater amount than the expense of making the joggle.

A better rule might be as follows: "Joggles should be provided for surface differences of 0.010 in. or more." An analysis should be made to determine whether or not a joggle would be the better construction.

Having determined that a surface difference necessitates an allowance, there is still a possibility of avoiding a joggle by interrupting the flange, as shown in Fig. 2. Sometimes this method is cheaper than joggling, particularly when the joggle is deep, since it presents no forming difficulties. However, it has the disadvantage of being structurally less rigid, and often cannot be used for this reason.

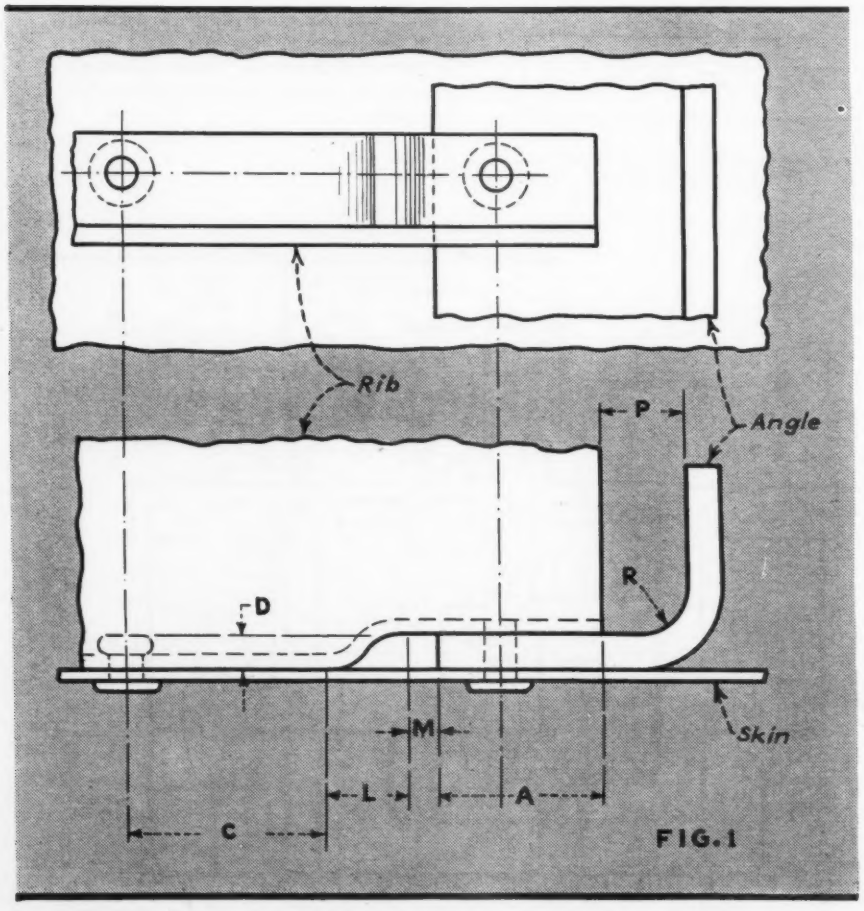


Fig. 1—A condition that requires a joggle.

Proportions of Joggles

The basic nomenclature for joggles is given in Fig. 3. The two arcs are assumed tangent, therefore would not be specified on a drawing because they are

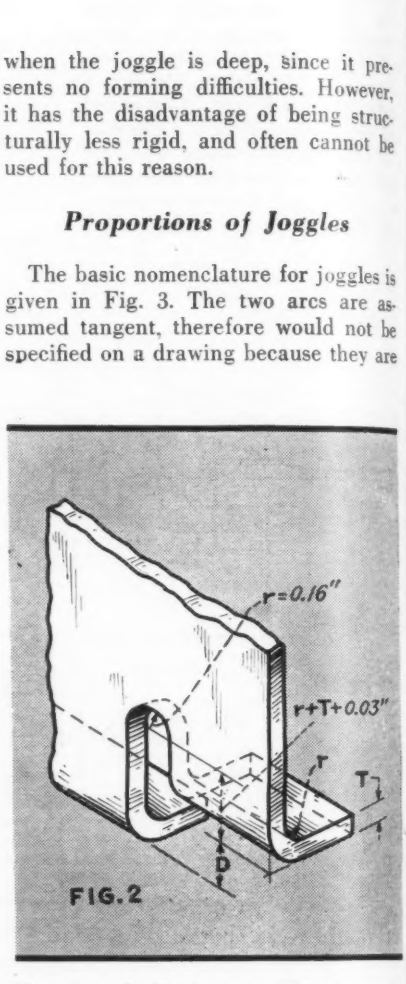


Fig. 2—A joggle can sometimes be avoided by interrupting the flange.

determined by D and L. Only the depth and length need be given. Tangent arcs are necessary to get the shortest L for a given D. In the rare instances where a long joggle is desired with a flat section between the arcs, the radii can be specified in addition to length and depth.

The relationship between R, D and L, which makes them dependent, is derived with the help of Fig. 4. The angle β is the bend angle, or angle subtended by the arc.

$$(2R + T)^2 = L^2 + (2R + T)^2 - 2D\,(2R + T) + D^2$$

or

$$L^2 = 2D\,(2R + T) - D^2 \quad (1)$$

Let $D = k \cdot T$ and $R = b \cdot T$

Then

$$L = \sqrt{(4b + 2)k - k^2}\,T \quad (2)$$

Also $L = \sqrt{\frac{4b+2}{k} - 1} \cdot D$ (3)

Let $p = \sqrt{\frac{4b+2}{k} - 1}$ (4)

Then $L = p\,D$ (5)

The proportionality factor p is important in the design of a joggle. It is a function of k, the ratio of depth to stock thickness, and of b, the ratio of bend radius to stock thickness. The latter ratio is set arbitrarily; then p is a function of k, which is already determined when the time comes to proportion the joggle. The value of p is often set arbitrarily, for example it often is given as 3. This value need be considered only as a minimum, because any larger value of p will yield larger values of R, which are satisfactory with reasonable limits.

Actually, no one arbitrary minimum value of p can be satisfactory. In order to make it large enough to take care of small values of k, it would be too large to be practicable for other applications. Thus it is necessary to tabulate suitable values of p for various values of k. This has been done for aluminum alloy 24-S in Table I using the following values of b as a basis.

Values of $b = R/T$	
	T = 0 to 0.102
24 S-O, β < 60 deg.	$b = 1$
$\beta \geqq$ 60 deg.	$b = 1\frac{1}{2}$
24 S-T, β < 60 deg.	$b = 3$
$\beta \geqq$ 60 deg.	$b = 3\frac{1}{2}$
	T = 0.102 to 0.250
24 S-O, β < 60 deg.	$b = 2$
$\beta \geqq$ 60 deg.	$b = 2\frac{1}{2}$
24 S-T, β < 60 deg.	$b = 4$
$\beta \geqq$ 60 deg.	$b = 5$

Using these values of b, p is represented as 8 functions of k, as follows:

b	p	b	p
1	$\sqrt{(6/k) - 1}$	3	$\sqrt{(14/k) - 1}$
$1\frac{1}{2}$	$\sqrt{(8/k) - 1}$	$3\frac{1}{2}$	$\sqrt{(16/k) - 1}$
2	$\sqrt{(10/k) - 1}$	4	$\sqrt{(18/k) - 1}$
$2\frac{1}{2}$	$\sqrt{(12/k) - 1}$	5	$\sqrt{(22/k) - 1}$

Angle $\beta = \arccos\left(\frac{2b+1-k}{2b+1}\right)$ (6)

Table I—Proportionality Factors (p) for Given k Values for 24-S Aluminum

	24S-O		24S-T	
D = kT	T < 0.102	0.102 ≷ T < 0.250	T < 0.102	0.102 ≷ T < 0.250
D ≷ 0.2T	5½	7	8½	10
D = 0.3T	4½	6	7	8
D = 0.5T	3½	4½	5¼	6
D = 0.7T	2¾	3¾	4½	5
D = T	2¼	3	3¾	4¼
D = 1.5T	2	2½	3	3½
D = 2 T	1¾	2	2½	3
D = 3 T	1½	1¾	2	2½
D = 4 T	1	1½	1¾	2¼
D = 5 T	1	1¼	1½	2
D = 6 T	1	1	1¼	1¾
D = 8 T	1	1	1	1½
D = 9 T	1	1	1	1¼
D = 11 T	1	1	1	1

Before using Table I, joggles are classified according to the type of deformation necessary to produce them.

CLASS I: Joggles produced by bending only.

CLASS II: Joggles with deformation in addition to bending.

An example in Class I is a joggle in an otherwise flat area of a sheet. An example in Class II is a joggle in the flange of a flanged part.

In designing a joggle, the procedure is as follows:

(a) Determine D, depth needed.
(b) Determine T, stock thickness.
(c) Determine $k = D/T$.
(d) Find $p = L/D$ from Table I. If joggle is Class I, use p or any value larger up to $2p$. If joggle is Class II, in the same way use 3 or the value from the table, whichever is larger.

EXAMPLE I: Suppose $T = 0.064$ and $D = 0.093$. Then $k = 1.5$, and p from Table I is 2 for 24 S-O aluminum. Then length L would be 0.19 for Class I and 0.28 for Class II.

EXAMPLE 2: Suppose $T = 0.102$ and $D = 0.031$. Then $k = 0.3$ and p from Table I is 6 for 24 S-O aluminum. Then the length L would be 0.19 for either Class I or Class II.

In addition to proportioning the joggle, it is necessary to relate the joggle to the part. The necessary clearances involved are shown in Fig. 1. P is equal to the radius of the angle plus clearance, M, usually 0.06 in., A is the sum of the rivet edge distances needed.

In dimensioning the rib as a detail part, M would be added to A and the sum used as a single dimension locating the joggle from the end of the part. A clearance dimension, C, allows room for tools to flatten the rivet head. It is the radius of the rivet (or bolt) head plus a small amount to allow for mislocation.

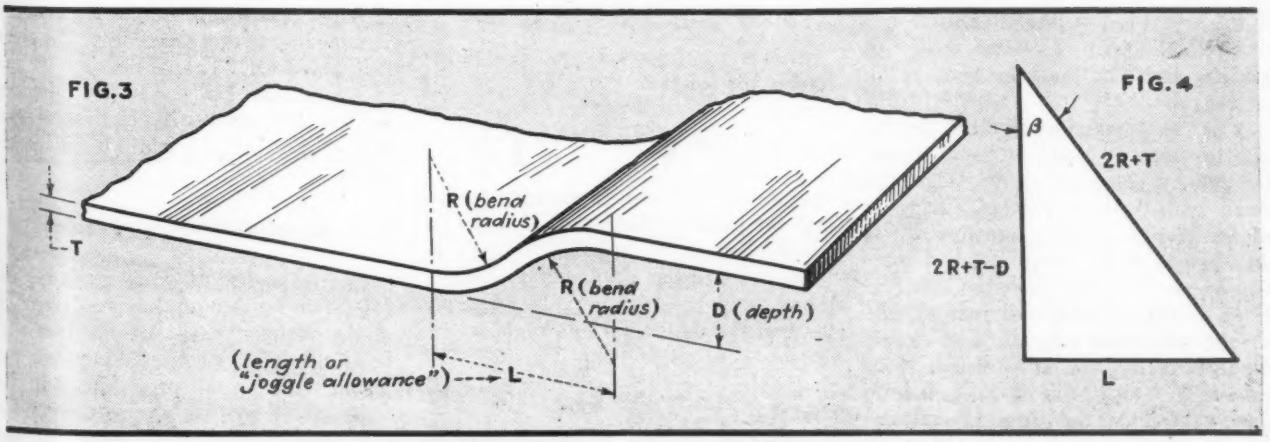


Fig. 3—Basic nomenclature for joggle dimensions and computation.
Fig. 4—Geometric relations for joggle dimensions are the basis of formulas.

Analysis of Inertia Forces In Reciprocating Engines

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Northwestern Technological Institute

Origin and nature of the inertia forces acting in a one-cylinder reciprocating engine with a semi-graphical method for determining their magnitude and direction. An analysis is included for the special case of a counterweighted crankshaft and its influence in reducing connecting rod effects.

FORCES in a reciprocating engine arise from two principal causes: (1) Gas forces, and (2) the inertia of the moving parts. Computations for the gas forces are generally kept separate from those caused by inertia. The two effects are then added together algebraically to find the total or resultant.

Centrifugal forces of the rotating masses of the engine mechanism can usually be mitigated by the application of suitable counterweights. But the forces and effects of reciprocating masses such as pistons and connecting rods are not so easily balanced. Engineers often make no attempt to counteract these forces, but merely determine their magnitude when designing the mounting or foundation of the machine.

The connecting rod of an engine moves with a peculiar motion, and generally has a non-uniform cross-section. In making a force analysis, the actual rod is usually imagined as being removed from the engine and replaced by a kinetically equivalent system consisting of two concentrated weights. That none of the dynamical properties of the engine be changed it is necessary that the system of two weights be the same as the actual rod in three qualities: (1) Same total mass, (2) same center of gravity, and (3) same moment of inertia.

A natural method of dividing the rod into two masses would be to determine the gravity reactions at the large and small ends with a pair of scales as shown in Fig. 1 (*A*). Reaction W_1 is then placed at the crank pin, and reaction W_2 at the wristpin as shown in Fig. 1 (*B*). This method of dividing the weight will fulfill only the first two of the three conditions. The moment of inertia of W_1 and W_2 will be different from that of the actual rod. Thus any calculations made for the system shown in Fig. 1 (*B*) will be correct only so far as the inertia forces are concerned, but will be in error with respect to inertia moment.

To retain the moment of inertia of the actual rod, let the arrangement shown in Fig. 2 (*A*) and (*B*) be used. Here one weight W_b is placed at the wristpin, and the other weight W_e is located at some other point E on the imaginary rod.

Length e_2, Fig. 2 (*B*), can be determined experimentally by suspending the rod on a knife edge at the center of the wristpin hole as shown in Fig. 3. When the rod is swinging as a pendulum the motion is caused by the component of the weight W normal to the rod. For small values of ϕ this force can be taken as $W\phi$. The motion is opposed by the inertia moment $-I_b\, d^2\phi/dt^2$. Equilibrium of moments about B gives the equation:

$$Wb\phi = -I_b \frac{d^2\phi}{dt^2}$$

Moment of inertia I_b of the rod about B can be expressed as Wr^2_b/g where r_b is the radius of gyration about B, and g is the gravitational constant. Substituting, cancelling, and rearranging gives the equation

$$\frac{d^2\phi}{dt^2} + \frac{bg}{r_b^2}\phi = 0$$

This is a well known type of equation having the solution

$$\phi = C_1 \sin\sqrt{\frac{bg}{r_b^2}}t + C_2 \cos\sqrt{\frac{bg}{r_b^2}}t$$

The time required for the rod to make one complete oscillation is of more interest than is its angular position ϕ. Values of ϕ repeat after each oscillation, that is, each time the angle increases by 2π, and the time t_1 for one cycle is

$$t_1 = 2\pi\sqrt{\frac{r_b^2}{bg}} \qquad (1)$$

Equation (1) can be transformed to give length e_2 as follows. Where I_e is the moment of inertia about the center of gravity, the moment of inertia of the rod about B is

$$I_b = I_e + \frac{W}{g}b^2$$

Where r_e is the radius of gyration about the center of gravity, this equation becomes

$$r_b^2 = r_e^2 + b^2 \qquad (2)$$

The moment of inertia about the center of gravity using the weights of the kinetically equivalent system is

$$\frac{W}{g}r_e^2 = \frac{W_e}{g}(e_2 - b)^2 + \frac{W_b}{g}b^2 \qquad (3)$$

From Fig. 2 (*A*)

$$W_e(e_2 - b) = W_b\, b$$

Substitution in Equation (3) gives

$$Wr_e^2 = W_b\, b\,(e_2 - b) + W_e\, b\,(e_2 - b)$$

or

$$r_e^2 = b\,(e_2 - b) \qquad (3a)$$

Substituting the value of b^2 from Equation (2) gives

$$r_b^2 = e_2 b \qquad (4)$$

This value for r^2_b is substituted in Equation (1) and the result solved for e^2, or

$$e_2 = \frac{t_1^2\, g}{4\pi^2} \qquad (5)$$

When e_2 is found, weight W_e is easily obtained by taking moments about point B in Fig. 2 (*A*). Thus if the time for one swing of the rod as a pendulum is known, the kinetically equivalent system of Fig. 2 (*A*) and (*B*) is determined.

Acceleration of Piston

Inertia forces depend upon the acceleration or rate of change of velocity of the various parts. An equation will be derived for the acceleration of the piston. The usual procedure will be followed of writing an expression for the displacement x in terms of the variable time and then differentiating twice.

Let the origin be taken at the head end dead center with the x-axis vertically downward as shown in Fig. 4. The links are numbered 1, 2, 3, and 4 as shown. Link number 1 is the ground or main frame of the engine.

It is assumed that the linkage, without gas forces of any kind, is being operated at a uniform crank speed of ω radians per sec. by an external source of energy.

From Fig. 4

$$x = r + l - r\cos\theta - l\cos\phi \qquad (6)$$

In general it will be found more convenient to use angle θ exclusively and thus avoid the necessity of computing ϕ.

$$\sin\phi = \frac{r}{l}\sin\theta$$

Since

$$\cos\phi = (1 - \sin^2\phi)^{\frac{1}{2}}$$

Using the binomial theorem

$$\cos\phi = \left(1 - \frac{r^2}{l^2}\sin^2\theta\right)^{\frac{1}{2}} = 1 - \frac{r^2}{2\,l^2}\sin^2\theta + \ldots\ldots \qquad (7)$$

In nearly all practical cases two terms of the binomial expansion will be sufficient. Substituting in Equation (6)

$$x = r - r\cos\theta + \frac{r^2}{2\,l}\sin^2\theta \qquad (8)$$

Differentiation of Equation (8), and substituting

$$d\theta/dt = \omega$$

gives the value of the velocity V_b of the piston

$$V_b = \frac{dx}{dt} = r\omega\left(\sin\theta + \frac{r}{2\,l}\sin 2\,\theta\right) \qquad (9)$$

An additional differentiation of Equation (9) gives an equation for the acceleration of point B

$$A_b = \frac{d^2x}{dt^2} = r\omega^2\left(\cos\theta + \frac{r}{l}\cos 2\,\theta\right) \qquad (10)$$

This acceleration when the links are located as shown in Fig. 4 is directed vertically downward.

The crankpin A has the centrifugal acceleration

$$A_a = r\omega^2 \qquad (11)$$

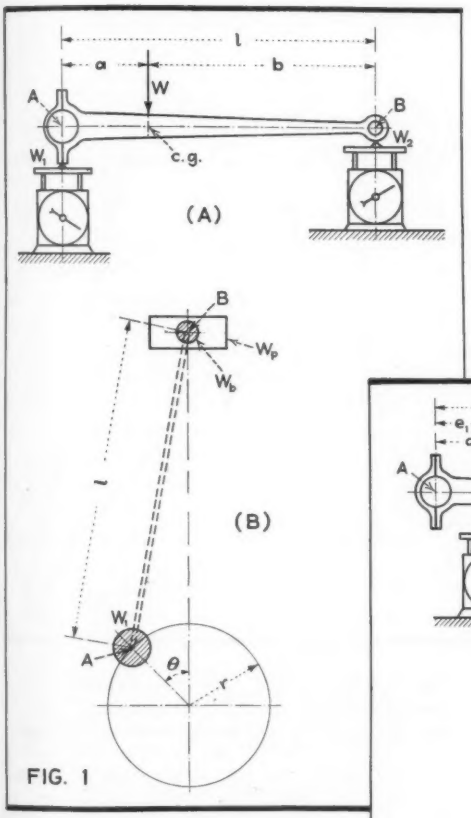


FIG. 1

Fig. 1(A)—Approximate method for determining the gravity reactions at the large and small ends of a connecting rod with a pair of scales. (B)—Rod replaced by gravity reactions.

Fig. 2(A)—Exact method for determining connecting rod reactions. (B)—Rod replaced by a kinetically equivalent system.

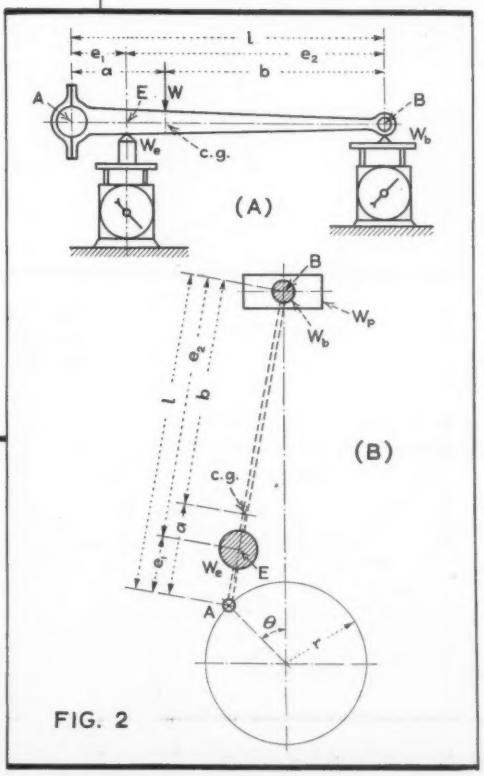


FIG. 2

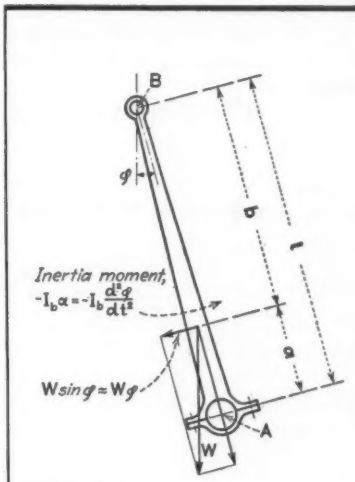


FIG. 3

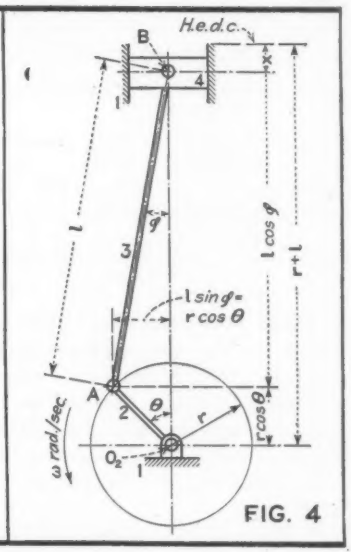


FIG. 4

Fig. 3—Method for determining the inertia moment of a connecting rod by suspending it from the center of the wrist pin and swinging it as a pendulum. Fig. 4—Displacement of piston in relation to crank angle.

It is directed radially towards the crank center O_2.

The acceleration polygon for the slider-crank mechanism of Fig. 4 can then be drawn as shown in Fig. 5. Accelerations A_a and A_b are plotted to scale both as to magnitude and direction. The vector joining the ends of A_a and A_b is the acceleration of B with respect to A, written A_{ba}. The polygon of these three vectors is a graphical representation of the vector equation

$$A_b = A_{ba} + A_a \qquad (12)$$

Acceleration A_{ba} is a relative acceleration, and is the acceleration which point B would appear to have to an observer located at A and moving with the mechanism.

It is also permissible to state

$$A_e = A_{ea} + A_a \qquad (13)$$

for the acceleration of point E. In this case also A_{ea} is the apparent acceleration of point E to an observer located at A and moving with the mechanism.

Since both B and E lie on the same radius from A, accelerations A_{ba} and A_{ea} will be proportional to their re-

spective distances from point A. That is

$$\frac{A_{ba}}{l} = \frac{A_{ea}}{e_1} \qquad (14)$$

These accelerations will have identical directions. Acceleration A_{ea} is computed from Equation (14) and the polygon is completed as in Fig. 5. The magnitude and direction of A_e is then scaled from the diagram.

Inertia Forces on Connecting Rod and Piston

Knowing the weights and accelerations three forces can be determined from Newton's law that inertia force is equal to mass times acceleration.

F_b = force at B resulting from W_b, the weight of rod at B.

F_p = force at B resulting from W_p, the weight of the piston.

F_e = force at E resulting from W_e, the weight of rod at E.

$$F_b = W_b A_b/g \qquad (15)$$

$$F_p = W_p A_b/g \qquad (16)$$

$$F_e = W_e A_e/g \qquad (17)$$

These forces have the same line of action as the accelerations of Fig. 5, but opposite in direction.

When the connecting rod and piston are taken together as the free body, two forces remain to be determined:

1. Force F_{23} of crankpin on the rod at A.

2. Force F_{14} of cylinder wall on piston at B.

The direction of F_{14} is known, but neither the direction nor the magnitude of force F_{23} is at hand. The force polygon for the rod and the piston can be completed by the following procedure.

Consider the connecting rod with force F_e acting as shown in Fig. 6. Force F_e can be divided into components normal and tangential to the rod. Component F^n_e is resisted at A by reaction F^n_{23} which by taking moments about B can be found.

The rod is also acted upon by other forces applied at A and B. Since A and B are frictionless turning pairs the rod is a two force member, and all forces applied at A and B (except the reactions resulting from F^n_e) must act parallel to the rod. Thus whatever the resultant force applied at A from the crankpin may be, it will have a component perpendicular to the rod equal to reaction F^n_{23}.

The inertia force polygon for the connecting rod and piston when taken together as the free body is shown in Fig. 7. Forces F_e, F_b and F_p are first plotted to scale both as to magnitude and direction, and the direction of F_{14} is also indicated. Component F^n_{23} as previously determined is next drawn, and component F^t_{23} (perpendicular to F^n_{23}) is drawn to intersect with F_{14}. Resultant F_{23} can then be drawn completing the polygon. Fig. 8 shows the connecting rod and piston in equilibrium under the action of the forces.

Equilibrium of Crank

Having the forces which are required to keep the connecting rod and piston in equilibrium, one proceeds to the equilibrium of the crankshaft as shown in Fig 9. Force F_{23} which the crankpin applies to the connecting rod is equal and opposite to force F_{32} which the connecting rod applies to the crankpin.

If the crank has a counterweight it will have an inertia force as shown. Reaction R_1^h and R_1^v of the bearing on the shaft are found by simple statics.

In general, a moment M_{shaft} is also required for equilibrium, this can be found from the equation

$$M_{shaft} = F^v_{32} r \sin\theta - F^h_{32} r \cos\theta \qquad (18)$$

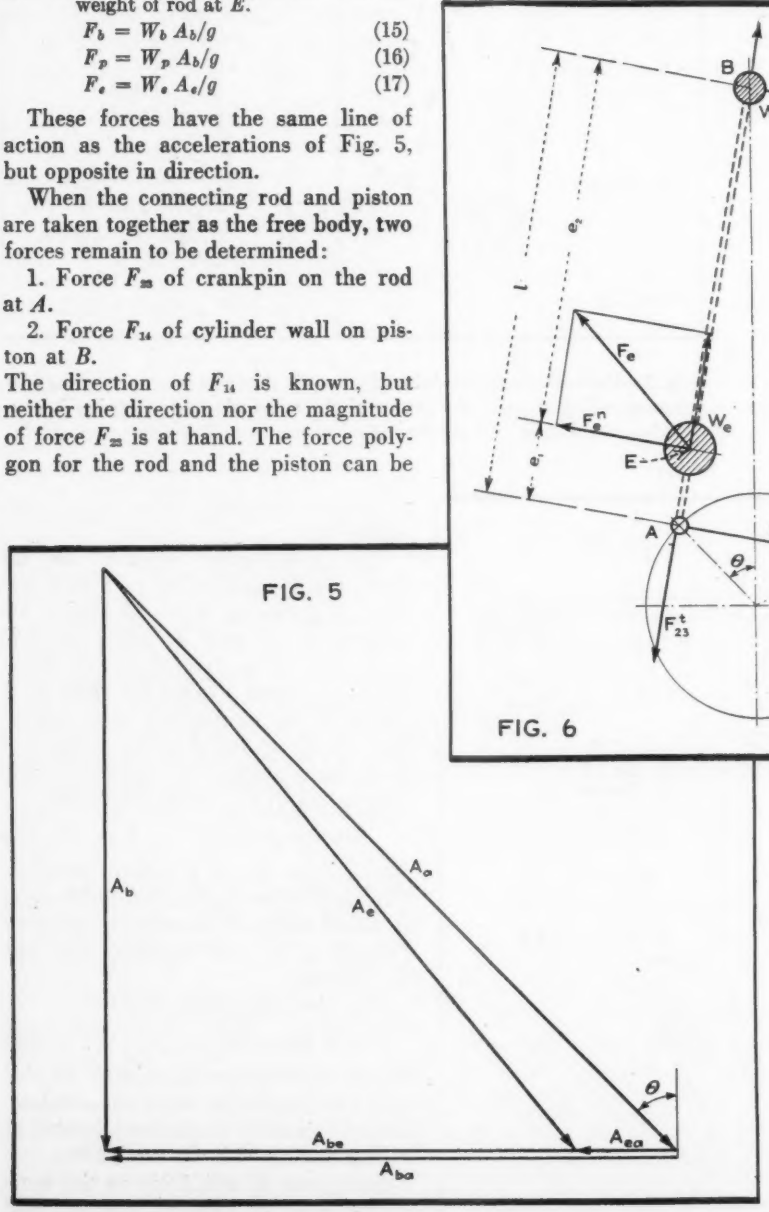


Fig. 5—Acceleration polygon diagram for reciprocating engine.

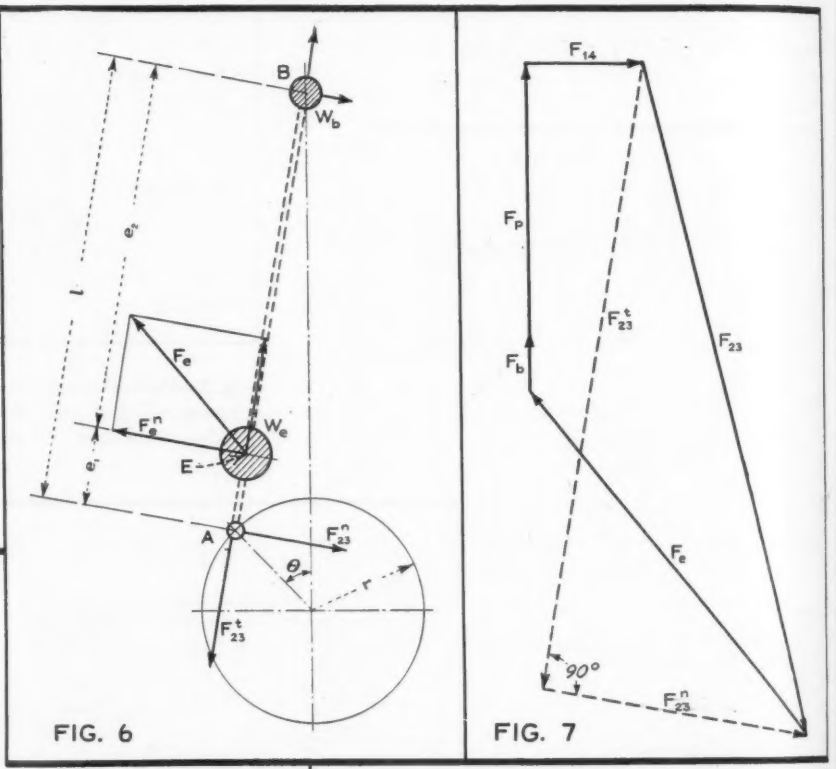


Fig. 6—Forces and reactions imposed on connecting rod. Fig. 7—Inertia force polygon diagram for connecting rod and piston.

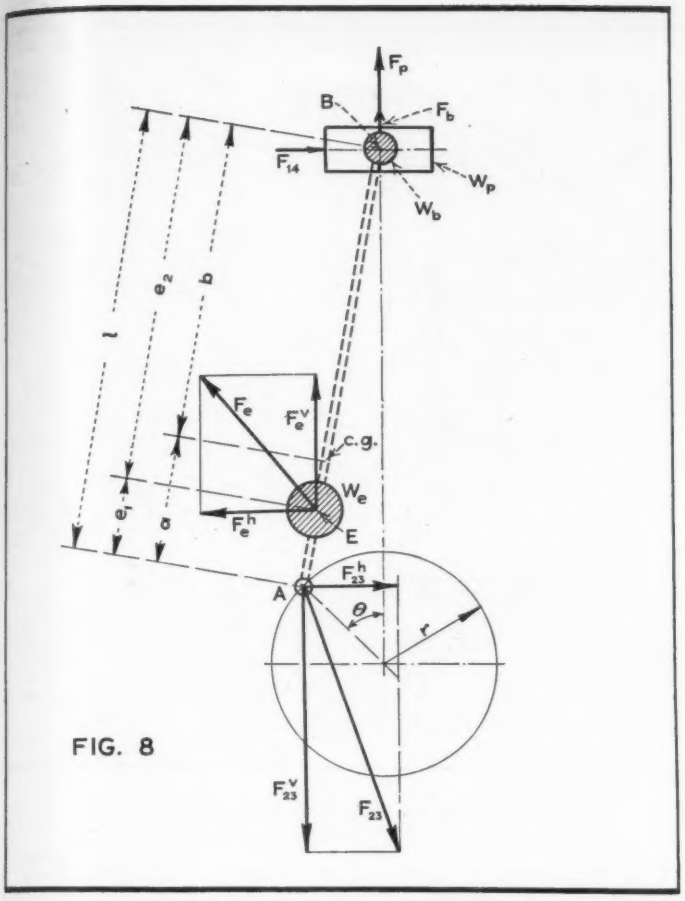


FIG. 8

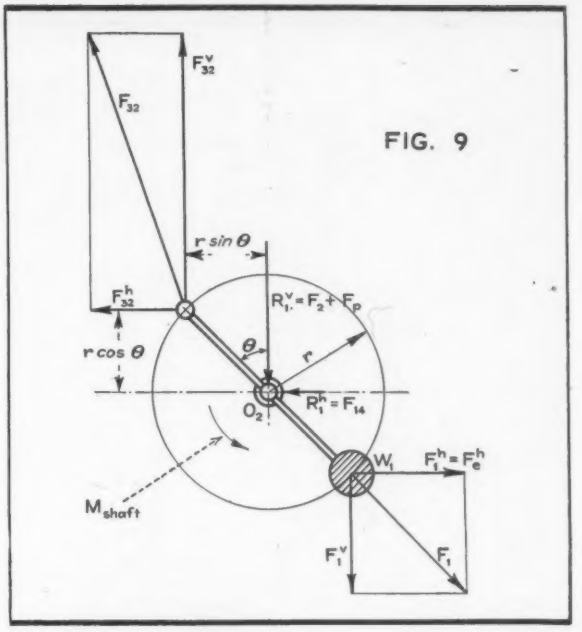


FIG. 9

Fig. 9—Equilibrium diagram of forces and reactions on crankshaft.

Fig. 8—Equilibrium diagram of inertia forces on connecting rod and piston.

When the links are in the position shown M_{shaft} must be supplied from an external source in order that equilibrium be maintained, and the linkage be kept moving at the given crank velocity of ω radians per sec. During other portions of the cycle, when the reciprocating parts are slowing down, the crank will be giving up energy to the external source and the direction of M_{shaft} will be accordingly reversed.

Special Case of Counterweight

The counterweight shown in Fig. 9 would usually be taken of such size as to compensate for the crankpin and cheeks as well as for a certain portion of the weight of the connecting rod. The reactions of the crankcase on the main shaft bearings, and consequently the reactions of the foundation on the crankcase are thereby reduced. Since the portion of the counterweight which opposes the crankpin and cheeks merely eliminates rotating masses from the problem, further discussion will be confined only to the portion which reduces connecting rod effects.

It will be advantageous to take this portion of the counterweight equal to W_1 the gravity reaction of the large end of the connecting rod as determined in Fig. 1 (*A*). As shown in Fig. 9, it is assumed that this mass is located at r.

It will be recalled that the total weight and center of gravity of the rod for the kinetically equivalent system remained the same as for the actual rod. Thus by Newton's law the total inertia force in any direction for W_a plus W_b is exactly the same as W_1 plus W_2. Forces F_a and F_b have already been determined. The equations for F_1 and F_2 are

$$F_1 = \frac{W_1}{g} A_a = \frac{W_1}{g} r\omega^2 \qquad (19)$$

$$F_2 = \frac{W_2}{g} A_b = \frac{W_2}{g} r\omega^2 \left(\cos\theta + \frac{r}{l} \cos 2\theta \right) \qquad (20)$$

Equating the horizontal and vertical components gives

$$F_a^h + F_b^h = F_1^h + F_2^h \qquad (21)$$

$$F_a^v + F_b^v = F_1^v + F_2^v \qquad (22)$$

Since the wristpin has only reciprocating motion the horizontal components of force are lacking, and

$$F_2^h = F_b^h = 0$$

and Equation (21) becomes

$$F_a^h = F_1^h \qquad (23)$$

Since these horizontal components are missing, Equation (22) can be rewritten as

$$F_a^v + F_b = F_1^v + F_2 \qquad (24)$$

It is now possible to represent the inertia forces and their reactions as they affect the engine as a whole, as shown in Fig. 10. Reactions R^v_1, R^h_1 and R_2 as well as the shaft M_{shaft} must be supplied to the engine from external sources.

The resultant vertical force R^v_1 is

$$R_1^v = F_a^v + F_b + F_p - F_1^v$$

Substitution from Equation (24) gives

$$R_1^v = F_2 + F_p \qquad (25)$$

The resultant upward force F_2 plus F_p becomes the downward force or reaction R_1^v of the foundation on the engine since equilibrium must be maintained. It should be noted that while Equation (25) was derived for the kinetically equivalent system of Fig. 2 it is also applicable to Fig. 1. Of course, if the counterweight is not made equal to W_1 the reactions will have different values than those shown.

Another expression can be derived from the conditions as shown in Fig. 10 for the shaft moment which will serve as a check on the result of Equation (18).

$$M_{shaft} = F_a^v d_2 + F_{14} l_1 - F_a^h d_1 \qquad (26)$$

The moment on the entire engine caused by R_{h1} and R_2 is generally called the frame moment. Its value is

$$M_{frame} = F_{14} l_1 \qquad (27)$$

In an actual engine, supports carrying reaction forces R^h_1 and R_2 would not be present. These forces being equal and opposite have no horizontal re-

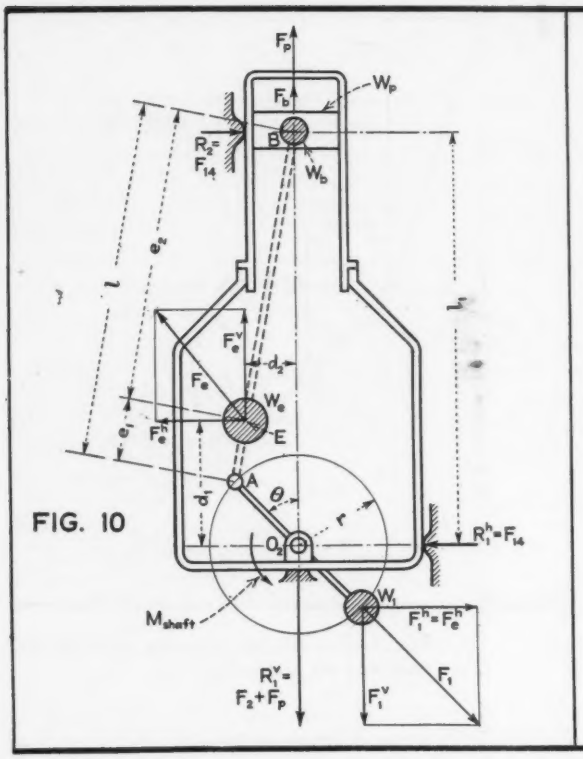


Fig. 10 — Equilibrium diagram of inertia effects for entire engine.

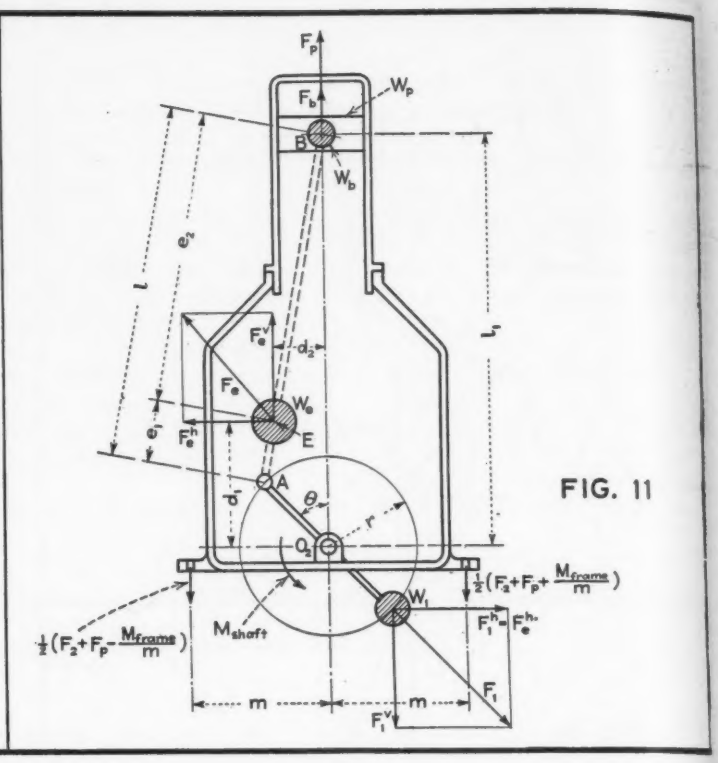


Fig. 11—Equilibrium diagram for vertical engine with mounting lugs on frame for holding down bolts.

sultant. These reactions can then be taken care of by a pair of vertical forces, as shown in Fig. 11, one directed upward and one downward, equal to $F_{14}l_1/2m$ located at the mounting lugs.

It must be kept in mind at all times that while force equations apply equally to either Fig. 1 or Fig. 2, all equations pertaining to moments must be derived from the conditions shown in Fig. 2, that is, the kinetically equivalent system.

The physical difference between shaft moment and frame moment is now apparent. The shaft moment, being the torque required at the shaft to keep the linkage in equilibrium, must be the resultant moment of all the forces which act on the mechanism. On the other hand, the frame moment is the moment which the foundation must exert on the machine to preserve equilibrium.

Application of Method

A numerical example will be solved to show how the method as described is applied. Let

Stroke = $2r = 5\frac{1}{4}$ in., $r = 2\ 5/8$ in.
Length of connecting rod, $l = 10.281$ in.
Total weight of connecting rod, $W = 2.20$ lb.
Large end reaction, $W_1 = 1.57$ lb.
Small end reaction, $W_2 = 0.63$ lb.
When suspended at center of wristpin hole, $t_1 = 0.93$ sec. for one complete oscillation
Weight of piston, wristpin and rings, $W_p = 1.50$ lb.
R.p.m. = 2,000 uniform
Crank position, $\theta = 45$ deg. with vertical
Counterweight = $W_1 = 1.57$ lb., exclusive of mass required for cheek and pin.

The results in successive steps of the procedure are

$$\omega = \frac{2{,}000 \times 2\pi}{60} = 209.4 \text{ radians per sec.}$$

From Fig. 1 (*A*),

$$b = \frac{W_1 l}{W} = 7.337 \text{ in.}$$

$$a = \frac{W_2 l}{W} = 2.944 \text{ in.}$$

From Equation (5)

$$e_2 = \frac{t_1^2 g}{4\pi^2} = \frac{0.93^2 \times 386}{4\pi^2} = 8.457 \text{ in.}$$

$$e_1 = l - e_2 = 1.824 \text{ in.}$$

From Fig. 2 (*B*),

$$W_e = \frac{Wb}{e_2} = 1.909 \text{ lb.}$$

$$W_b = \frac{W(a - e_1)}{e_2} = 0.291 \text{ lb.}$$

$$\frac{r}{l} = \frac{2.625}{10.281} = 0.2553$$

$$\sin\phi = \frac{r}{l}\sin\theta = 0.1805,\ \phi = 10 \text{ deg. } 24 \text{ min.}$$

$$A_b = r\omega^2\left(\cos\theta + \frac{r}{l}\cos 2\theta\right) = 6{,}830 \text{ ft. per sec.}^2$$

$A_a = r\omega^2 = 9{,}596$ ft. per sec.^{2}

Constructing Fig. 5, gives $A_{ba} = 6{,}785$ ft. per sec.^{2}

$$A_{ca} = \frac{e_1}{l} A_{ba} = 1{,}200 \text{ ft. per sec.}^2$$

Plotting on Fig. 5, gives $A_e = 8{,}780$ ft. per sec.^{2} inclined at 39 deg. 28 min. to vertical

$$F_e = \frac{W_e}{g} A_e = 521 \text{ lb.}$$

Construct Fig. 6, and find $F_e^n = 398$ lb. Taking moments about B gives $F_{23}^n = 327$ lb.

$$F_b = \frac{W_b}{g} A_b = 62 \text{ lb.}$$

$$F_p = \frac{W_p}{g} A_b = 318 \text{ lb.}$$

Plot F_e, F_b, F_p and F_{23}^n as in Fig. 7. Complete diagram and determine:

$F_{14} = 142$ lb., $F_{23} = 805$ lb. at angle 13 deg. 35 min. to vertical.

Draw Fig. 8 showing all forces. The following components are obtained

$F_e^v = 402$ lb., $F_e^h = 331$ lb., $F_{23}^v = 782$ lb., and $F_{23}^h = 189$ lb.

Draw Fig. 9, for centrifugal force of counterweight:

$$F_1 = \frac{W_1}{g} A_a = 468 \text{ lb.}$$

$F_1^v = F_1^h = 331$ lb. (for $\theta = 45$ deg.)

From equilibrium determine:

$R_1^v = 451$ lb., and $R_1^h = 142$ lb.

From Equation (18)

$M_{shaft} = 782 \times 1.856 - 189 \times 1.856 = 1{,}100$ in. lb.

Draw Fig. 10, from equilibrium obtain:

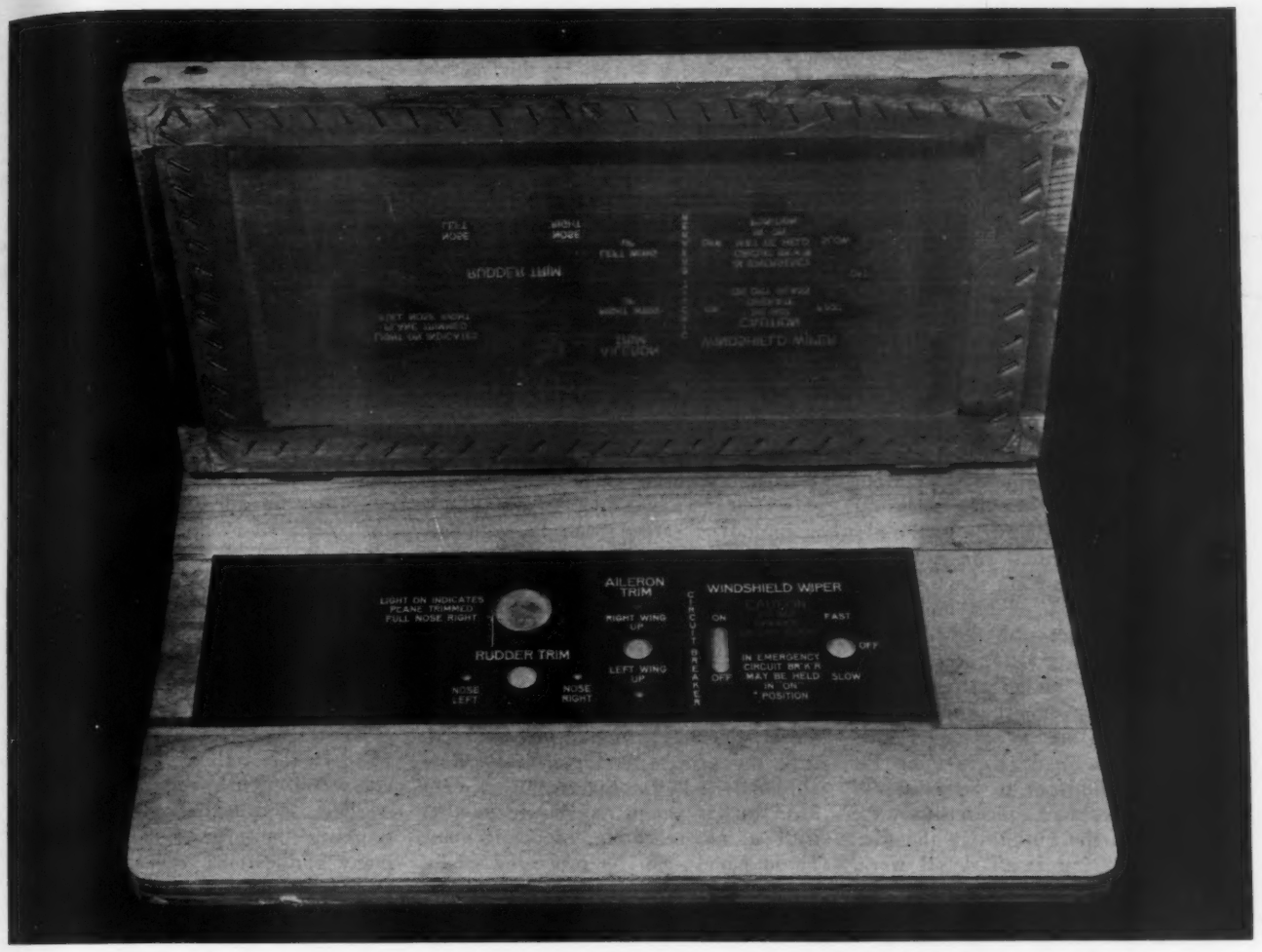
$R_1^v = 451$ lb., and $R_1^h = R_2 = F_{14} = 142$ lb.

From Equation (26)

$M_{shaft} = 402 \times 1.527 + 142 \times 11.967 - 331 \times 3.650 = 1{,}100$ in. lb.

From Equation (27)

$M_{frame} = 142 \times 11.967 = 1.700$ in. lb.



Typical silk-screen set-up includes a hinged screen on an index board. Two colors are processed with this screen. The first is applied, allowed to dry and then masked before the second color is added.

Silk-Screen Process Applied For Aircraft Panel Markings

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Swift marking process conforms to mass production of planes. Permits application of lettering and designs to accessories and panel plates where surfaces are flat or contoured. Variations of the method are described and illustrated.

THE silk-screen process of applying letters, numerals, designs and insignia to flat or contoured surfaces has wide application but is little understood. It consists essentially of squeegeeing paint through a tightly drawn silk or fine-mesh screen that has been suitably masked.

When airplanes were being built more or less to individual specifications in limited quantities, painted engravings or etchings were satisfactory for marking signs, placards and instruction plates. Mass production of aircraft gave rise to a need for a faster method of marking instruction plates. The silk-screen process has proved satisfactory.

Successful adaptation of the silk-screen process to aircraft indicates other possible applications. Need for quantity production of markings is an important consideration before installing equipment for silk-screen reproduction. The type of screen selected for a specific application will determine whether or not a given initial cost spread over the number of pieces to be

processed will be economical. There are actual instances where a single silk-screen reproduction cost less and was an improvement over reproduction by conventional sign painting methods.

Two types of screens are in general use. The silk-screen process industry refers to them as the film and photographic methods. Several other methods are in existence but they have limited applications. There are two film methods: (1) film is attached by means of a heated iron, and (2) film is attached using an adhesive. Type of film determines which method is used.

Both methods involve use of a stencil sheet comprising a backing sheet of transparent material to which a transparent film is superimposed. Film and backing sheet are placed on a desired design and a cutout is made on the film with a stencil knife. The cutout is peeled from the backing sheet and the stencil sheet is placed on the screen which is in contact with the film. The cutout is then fastened to the screen by a heated iron or an adhesive and the backing sheet is removed by peeling, leaving the film on the screen. Reproduction is then made by placing the screen on the surface to be processed and using a rubber squeezer to force paint through the outlines in the film.

For reproducing small detail work, such as appears on instruction and instrument panels, the photographic or sensitized-screen process is employed. In preparing a screen by this method the fabric is coated with a sensitized emulsion. After proper drying and setting-up, a transparent copy of the design or lettering is placed on the sensitized screen and the whole exposed to a strong light. Portions exposed to the light are hardened by developing and the unexposed portions are washed away with running water. Reproduction is then accomplished as before.

The making of screens by the photographic process is somewhat involved and requires considerable equipment. Installation of this equipment is recommended only if large quantities of screens are to be made. Most large cities have job shops where photographic-type screens can be obtained.

Little equipment is required in establishing a silk-screen unit in the paint shop if the film methods are employed. A process table with an inclined top and a number of drawers for storing materials is necessary. Racks for storing finished screens and processed parts during the drying period are essential.

Screen processing for aircraft panel applications is, for the most part, confined to flat panels previously painted with a non-reflecting black lacquer. These panels can be processed easily before assembly of component parts. Processing of finished assemblies often requires care in making frames with proper cutouts.

It has been found that addition of small amounts of varnish extender to process color paints results in hard, wear-resisting, slightly raised lettering that often withstands a normal amount of handling better than decalcomanias. The marking is fine, distinct, easily read and has excellent contrast against reflecting surfaces inside compartments.

The silk-screen process has proved worthwhile for making exterior marking on aircraft. A portable cart containing all the screens and a container of cleaning solvent is used. Two operators, one applying screens and the other washing them, can complete the markings on an airplane in less time than required by the conventional stencil-spray methods. Quality of the marking is considered superior. A silk screen can be made in a few hours whereas engravings for decalcomanias take days to produce, and delivery of some types of decalcomanias is a matter of weeks.

No attempt has been made to explain in detail all of the fine points of silk-screen processing. Handled by workers of experience and aptitude, however, the process can be used in many applications to increase production, save time and lower costs.

Recent Progress in Synthetic Rubbers

"IN THE field of automotive mechanical goods . . . the special-purpose synthetics had established themselves in many uses due to their superior performance and in spite of their higher cost," said P. M. Torrance, Firestone Tire & Rubber Company, in describing recent progress in synthetic rubbers before a meeting of the Cleveland Section of the Society of Automotive Engineers. "You are all familiar with the oil-resistant Neoprene water-pump seal, which was an almost miraculous improvement over the old mechanical packings. Such seals may also be made of Buna N, when it is available in sufficient quantities.

"Radiator hose is much better made of the oil-resistant synthetics, especially in these days of rust inhibitors and closed-pressure cooling systems. Oil-resistant brake hose may make improved types of brake fluids practical . . . Synthetics show great promise in fan belts, especially Neoprene, where its oil resistance is of some advantage.

Motor mounts present a number of problems, particularly due to the greater hardness of the synthetics. It has not yet been possible to make the extremely soft 30-durometer stocks and this may necessitate redesign of some types. Seals, grommets, gaskets, insulators and dust covers create no serious problems and, in most cases, the oil-resistant synthetics give superior performance. Channel rubbers for windshields, windows, door edgings, etc., can be made from synthetic without difficulty. Windshield wipers are actually improved because they do not get gummy and tacky.

"Chemical research will produce much better synthetics. It is even probable that they will surpass natural rubber in other properties as they have already surpassed natural rubber in oil resistance. There is no good reason to believe that Mother Nature, in creating the natural latex of the rubber tree, designed the best possible material for tread wear, heat generation and other desirable characteristics. There are numerous well-known samples of man-made synthetic products created for specific purposes which have far surpassed the natural materials previously used. In our own tire industry, we have high-tenacity rayon fibers, which give vastly superior results to natural-cotton fibers. This was not accomplished over night, but was the result of many years of painstaking research and development. At the present time. Nylon fibers give every indication of doing a still better job. Given sufficient time, there is every reason to believe that synthetic rubbers will be created vastly superior to the present materials.

"After the war it is entirely probable that we will resume the use of natural rubber for at least part of our requirements. It is doubtful if it will be permitted to replace synthetic beyond a certain point because of the desirability of maintaining our own rubber supply for military reasons. On the other hand, it will probably be desirable that we give some business to the rubber producers in the Far East, even when we have improved synthetics. It is imperative that the rubber industry make every effort to develop superior synthetic rubbers, which can be produced economically, so that we will never again risk the disaster of being cut off from our sources of such a vital material as rubber."

INDUSTRY AND SOCIETIES

NEWS • READER LETTERS • MEETINGS

C.E.D. Recommendations Foster Small Business

SPECIAL CONSIDERATION during the post-war reconversion period and a program of assistance thereafter for small business are proposed by the Committee on the Special Problems of Small Business of the Committee for Economic Development. The committee states that "the opportunity to start a new business and the health of existing small businesses are essential to a dynamic and virile economy after the war and to the preservation of our free society." A number of measures, both national and local, are proposed. Among the former are:

1. Special consideration in the termination of war contracts and disposal of government-owned plants and surpluses, and fair treatment in the allocation of materials to help small business resume peacetime operations.

2. Recommendation that smaller firms able to reconvert more rapidly than large establishments not be required to wait until the latter are ready for production.

3. Constructive recommendations for local aid in financing.

4. Exploration of possible provision for adequate tax relief after the war.

5. Dissemination of information on modern business techniques and various new developments in business operations through joint efforts of the federal and state governments, educational institutions and business.

6. Special encouragement for returning servicemen to go into business for themselves, with increased emphasis by educational institutions on "the desirability of independent small business as a career."

Recommendations as to possible aid to small business locally include:

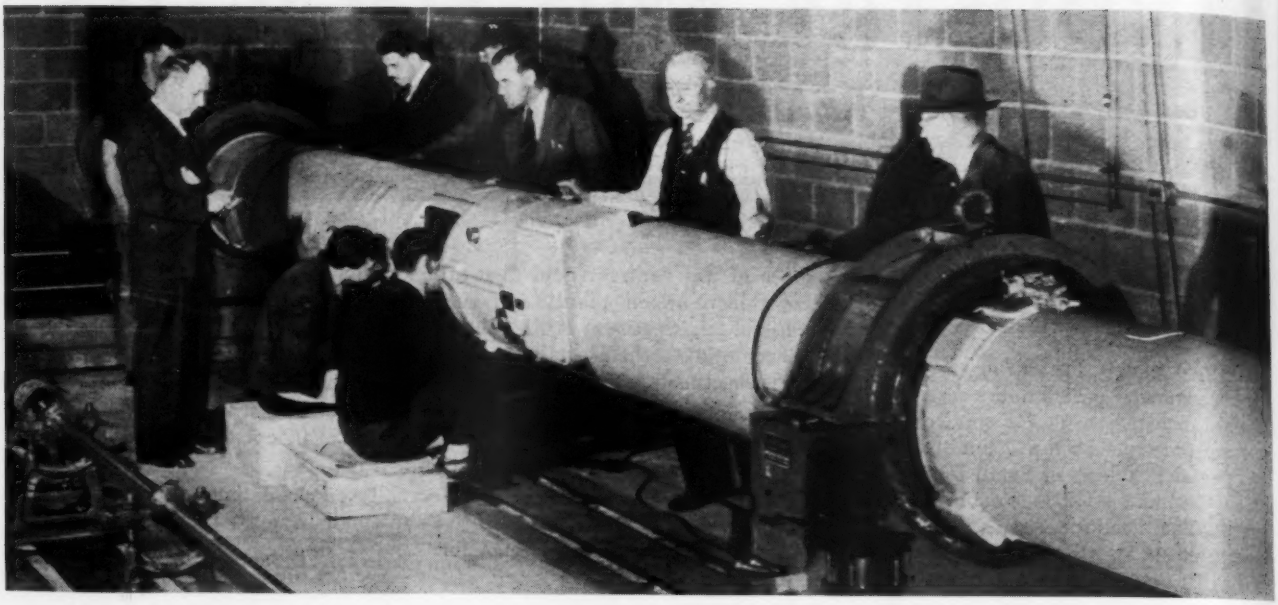
1. Local "action groups" to assist local small business to find needed capital at reasonable cost.

2. Community action to make available at cost such laboratory and research facilties as will help small-scale enterprise to develop and market new products, either through voluntary pool-

Key Hydraulics Men Work on Standardization

To coordinate opinions about aircraft hydraulic equipment, and Army and Navy opinions about design and standardization of combat equipment, a series of coast-to-coast meetings is being held. Actual standards work is being done for the Army, Navy, British Air Commission and War Production Board by S.A.E. and N.A.S.C., the former representing hydraulic equipment manufacturers and the latter the aircraft manufacturers. Shown here are key hydraulics engineers, among more than 100 who attended the Mar. 20-25 joint meeting of the Society of Automotive Engineers-National Aircraft Standards Committee in Chicago. Seated, left to right, F. O. Hosterman, Lockheed; R. H. Davies, Parker Appliance; L. J. Henderson, Weatherhead; B. R. Teree, Airplane Division, Curtiss-Wright; J. D. Redding and Gladys Shumate, S.A.E. staff; Harry Kupiec, Glenn L. Martin, chairman; F. W. Murphy, Douglas; and Howard Field, Jr., Los Angeles, Calif. Standing left to right, John Sasso, PRODUCT ENGINEERING; W. V. Fitch, Harvill; J. Dentraygues, Lockheed; G. A. Rice, Aircraft Accessories; B. F. Ashton, Electrol; Andrew Raffay, Jr., Purolator Products; E. F. Loweke, Hayes Industries; B. C. Reciputi, Adel Precision Products; J. P. Kovacs, Purolator Products; B. P. Heineck, Bendix Aviation; and G. H. White, Adel Precision Products.

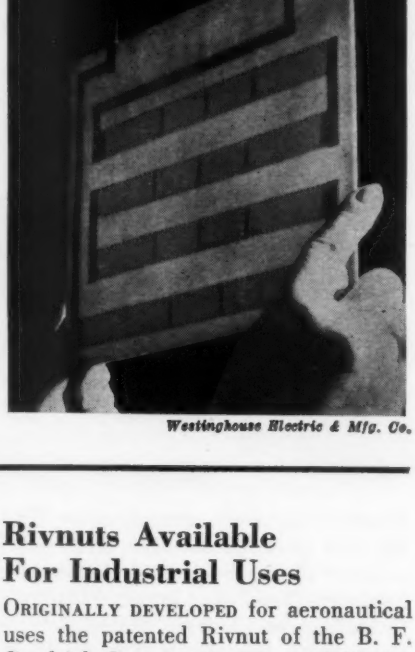
Big Range-Finder Takes Shock Test



Mounted in a "shock cradle" that reproduces the recoil of a battleship's 16-in. guns, this big range finder is being inspected following tests at the Bausch & Lomb Optical Company to shake alignment of its parts. There are 1,600 accurately made optical and mechanical parts in the tube. When a target is sighted trigonometric data are transferred from the range finder to the plotting room where it is combined with other data for aiming the guns.

Heater Maintains Storage-Battery Output

To keep up the output of storage batteries under sub-zero temperature conditions, when batteries deliver as little as one-fourth as much power as at normal temperatures, this resistance grid, which consists of 0.005-in. thick nickel-chromium ribbon embedded in acid-resistant Micarta molded under high pressure and heat, maintains the temperature at approximately 70 deg. F. when it is installed between batteries or built integrally into each unit.



Westinghouse Electric & Mfg. Co.

ing of the research facilities of the larger firms, as under the Toledo C.E.D. plan, or through special facilities made available by institutions.

3. Removal of possible obstacles such as may be found in building codes, local tax systems and license fees, and state and local trade barriers.

4. Promotion of studies, through existing organizations wherever possible, to foster new enterprises particularly adapted to the needs of the community.

Rivnuts Available For Industrial Uses

ORIGINALLY DEVELOPED for aeronautical uses the patented Rivnut of the B. F. Goodrich Company is now available for industrial applications that carry a minimum priority of AA-5. The Rivnut is an internally threaded and counterbored tubular rivet which can be headed blind. It is made from corrosive-resistant aluminum alloy. By using special tools, either manually or power-operated, the fastener can be pulled up or headed while working from one side, forming a bulge or head on the far side. This upset is large enough to resist being pulled through the material to which the Rivnut is applied.

When installed, the Rivnut serves as a nut plate or rivet, or both. Two head styles, countersunk and flat, are offered, with the countersunk made in three shapes and the flat in one. Each is made in three nominal sizes, available in six grip ranges. They can be supplied with open or closed ends, and with or without keys under the head in all except the thin head countersunk type.

Designers Merge To Form Partnership

VAN DOREN, NOWLAND & SCHLADERMUNDT has been formed as a new industrial design partnership by a merger between Harold Van Doren & Associates and Roger L. Nowland, Peter Schladermundt and Katherine B. Gray, former partners of Norman Bel Geddes. Offices are located in New York, Philadelphia and Toledo, Ohio. Accounts of the firm include automobile, aviation, machine tool and other capital goods industries, and radio, refrigerator and other consumer goods manufacturers.

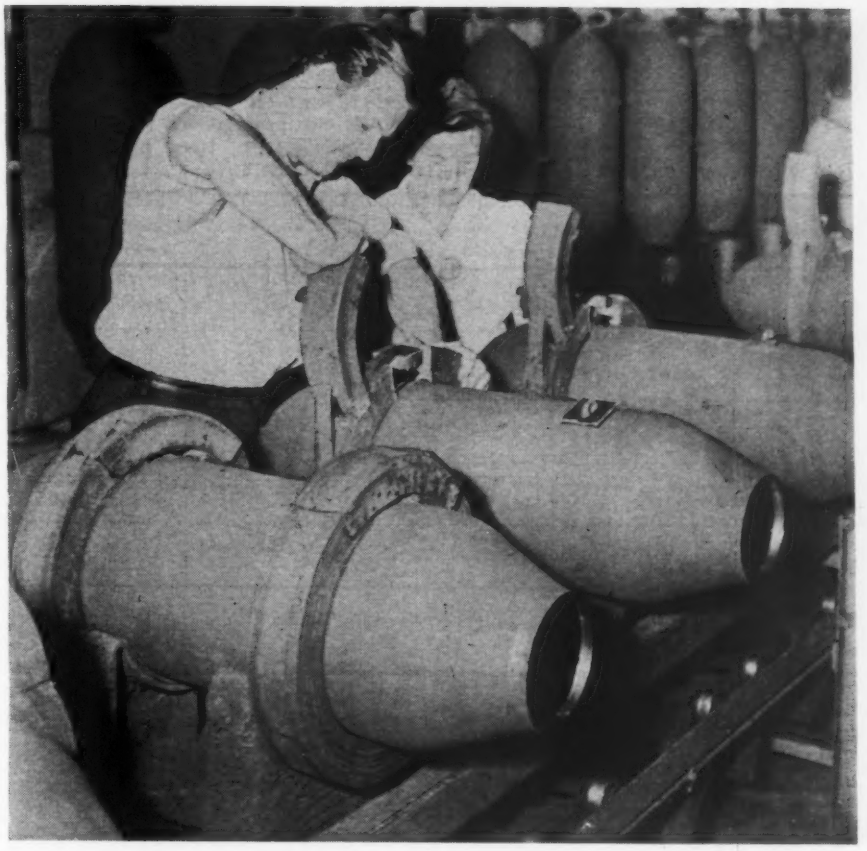
Mr. Van Doren is author of the text, "Industrial Design," and winner of the 1941 American Design Award; Mr. Nowland, special lecturer on product development and design at Massachusetts Institute of Technology, was one of the designers of the Curtiss-Wright "Hell Diver" and was chief design engineer of the World's Fair Futurama; Mr. Schladermundt, prior to being chief designer for Norman Bel Geddes & Company, was associated with Henry Dreyfuss in designing the New York Central "Mercury" and "Twentieth Century Limited"; Miss Gray was office manager and director of information at the New York World's Fair.

Post-War Product Design Promoted by Film

How INDUSTRIAL DESIGN can aid in the post-war planning activities of a manufacturing concern is dramatized in a sound-slide film called "Now Is the Time," produced by the Committee for Post-War Processes, Materials and Designs of the Committee for Economic Development. Film and record are available for $6.50 per set from C.E.D.'s national headquarters, 658 Madison Ave., New York 17, N. Y.

The film portrays the story of a firm confronted with the question of post-war products and follows the firm's investigation of new uses of materials in new designs to produce consumers' goods that look better, operate more efficiently and sell at a lower price. Wide dissemination of the ideas presented in the film is encouraged by showing it before civic organizations in addition to its use as a stimulator of planning by individual manufacturing concerns.

Paper Replaces Metal Bands for Bombs



Several layers of paper wound into a tube and impregnated with Uformite, a urea-formaldehyde-starch mixture, are now being used for "wheels" on all bombs up to 1,000 lb. The impregnated-paper bands protect the lugs on the bomb and make moving of the bomb easier. Use of these impregnated paper bands in place of metal ones saves enough steel to build 3,600 tanks annually. The resin-starch mixture enables the bands to withstand severe weathering, less than 3 percent moisture absorption in 24 hr. being the standard requirement. The bands were developed by Alton Box Board Company and Resinous Products & Chemical Company in cooperation with Army Ordnance.

Discussions and Comments From Readers

SECRET PASSWORD FOUND BY RECURRENT METHOD

To the Editor:

On page 139 of your February, 1944, number you published a problem the answer to which entitled the finder to membership in a secret mathematical society. Inclosed is the solution, but please do not enroll me in this society because I haven't the time to take part in any more organizations if I am to do my part in winning the war by filling out my quota of questionnaires.

The problem involved a disk which rested at point A on a plane. The disk was rolled forward without slipping until the point A' that was in contact with point A intersects a straight line drawn from point A through the center of the circle. The problem was to find the angle in radians that this line makes with the plane.

From the conditions of the problem

$$\text{length } AB = \text{arc } BA' = \beta R$$

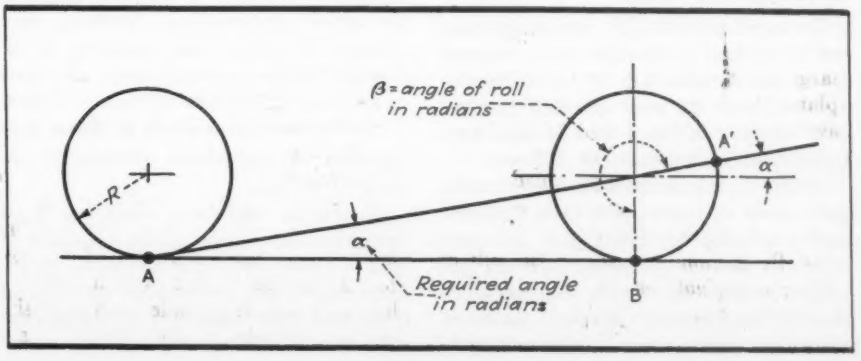
$$\tan \alpha = \frac{R}{AB} = \frac{R}{\beta R} = \frac{1}{\beta} \qquad (1)$$

$$\beta = \frac{3\pi}{2} - \alpha \qquad (2)$$

Substituting Equation (2) in Equation (1) there results

$$\tan \alpha = \frac{1}{3\pi/2 - \alpha} \qquad (3$$

(continued on next page)



Trial No.	(1)	(2)	(3)	(4)
n	α_n	$\frac{3\pi}{2} - \alpha_n$	1/(2)	$\tan^{-1}$ (3)
1	0.3927	4.3197	0.2315	0.2275
2	0.2275	4.4849	0.2229	0.2194
3	0.2194	4.4930	0.2225	0.2190
4	0.2190	4.4934	0.2225	0.2190

Trial No.	(1)	(2)	(3)	(4)
n	α_n	$270 - \alpha_n$	$\frac{57.29578}{(2)}$	$\tan^{-1}$ (3)
1	12.5725	257.4275	0.22257	12° 32′ 52″ 12.5478
2	12.5478	257.4522	0.22255	12° 32′ 48″ 12.5467
3	12.5467	257.4533	0.2225482	12° 32′ 47.64″ 12.54657

$$\alpha = 12.54657 \text{ deg.} = \frac{12.54657}{57.29578} = 0.21898 \text{ radians}$$

Solving Equation (3) by the recurrent method there results the calculations shown in the first table above. The first trial value for α was taken as $\frac{1}{18}$ of a circle.

This value for α is correct to four places, but perhaps the value should be corrected to five places. To do this I will have to use another set of trig tables and convert α into degrees. Therefore,

0.2190 radians=12.5725 degrees.

Also Equation (3) must be restated in terms of degrees, as

$$\tan \alpha = \frac{57.29578}{270 - \alpha}$$

Using the recurrent process again there results the second table above.

—J. Osker

SUBSCRIPTION POLICY DETERMINED BY PAPER

Numerous complaints are being received by the editors of Product Engineering from subscribers who have permitted their subscriptions to expire and now find that they cannot get them renewed immediately. On account of the paper shortage only a limited number of copies can be printed. This has resulted in a subscription waiting list of more than a thousand names. It is important, therefore, that subscribers who wish to assure continuity of their subscriptions send their renewal as soon as they are notified that the subscription is about to expire. Renewals received after expiration of the subscription must be placed on the waiting list.

Activities Among Technical Societies

MEMBERSHIP REQUIREMENTS ALTERED BY A.D.I.

To meet present-day conditions and needs of the profession, new requirements for membership in American Designers' Institute were adopted at a recent meeting of the board of directors. Qualifications are now as follows:

Active members shall be those having four years of experience as a designer and are now designing for industry, which is defined as being actively engaged in creating forms for machines and/or equipment and/or products made by quantity production methods.

Associate members shall be assistant designers, draftsmen not yet qualified for active membership, directors, consultants in design and teachers of industrial design, and may enjoy all rights of active members except that of voting.

Student members shall be those now enrolled in accredited schools of industrial design.

Sustaining members shall be those interested in sponsoring the activities of A.D.I. These may be individuals, manufacturing firms, institutions or associations and may have full privileges except that of voting.

Honorary members shall be those persons who, in the opinion of the members, have rendered distinguished service to art in industry.

Contributors shall be those who wish to express their interest by a substantial contribution.

Sponsors shall be those connected with educational institutions, foundations, museums, etc., who will sponsor the educational aims and ideals of the American Designers' Institute.

HEAT TRANSFER RESEARCH PROJECT ESTABLISHED

Made possible by a $75.000 grant from Westinghouse Electric & Manufacturing Company, a five-year training and research program has been established at Purdue University for the "intensive training of graduate students in exploring the field of heat transfer for data upon which many of the practical developments of the future depend." Dr. George A. Hawkins, professor of mechanical engineering, has been appointed Westinghouse research professor in heat transfer to head the project. Dr. Max Jacob, of Illinois Institute of Technology, will cooperate in the capacity of non-resident research professor. Research fellows will have access to the heat transfer laboratory of Purdue's School of Mechanical and Aeronautical Engineering as well as facilities of other departments.

Meetings

American Society of Mechanical Engineers—Oil and gas power division meeting, May 8-10, Tulsa, Okla.

Society of the Plastics Industry—Annual meeting, May 11-12, Edgewater Beach Hotel, Chicago, Ill.

American Gear Manufacturers Association—Spring meeting, May 22-24, Westchester Country Club, Rye, N. Y.

Society of Automotive Engineers—National war materiel meeting, June 5-7, Book-Cadillac Hotel, Detroit, Mich.

American Society of Refrigerating Engineers—June 6-8, William Penn Hotel, Pittsburgh, Pa.

Do You Know That—

Only about 30 percent of a tree that is cut for lumber and other products is utilized, the other 70 percent going to waste. (19)

Synthetic rubber that approaches natural rubber in processing characteristics has been developed. (20)

New Books

Basic Mathematics For War and Industry

PAUL H. DAUS, JOHN M. GLEASON *and* WILLIAM M. WHYBURN. 277 *pages*, 5½ x8⅜ *in., blue clothboard covers. Published by Macmillan Co., 60 Fifth Ave., New York, N. Y. Price* $2.

This book is intended to provide a single text in which selected principles of elementary mathematics are presented in a carefully organized manner. It is divided into five chapters covering arithmetic, algebra, geometry, plane trigonometry, and solid geometry and spherical trigonometry. Illustrations and problems chosen from many fields give it a thoroughly practical aspect.

Analytical And Applied Mechanics

G. R. CLEMENTS and L. T. WILSON. 475 *pages*, 5¼x8¼ *in., blue clothboard covers. Published by McGraw-Hill Book Co., 330 W. 42nd St., New York* 18, *N. Y. Price* $3.75.

This second edition, although similar in purpose and objective to the first edition, contains many changes in the presentation of material and illustrations. Problems have been revised and many new ones added. Basic principles of mechanics are discussed clearly and thoroughly, both analytically and in relation to their application in engineering design. Problems are especially selected to give the student practice in applying the principles covered in the text. Included in the subjects treated are forces, statics, framed structures, cables, center of gravity, moment of inertia, hydrostatics, stress and strain, beams, motion, kinetics, work, energy and dynamics.

Practical Metallurgy for Engineers

Published by E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, *Pa.*, 480 *pages*, 5½x8½ *in., blue clothboard covers. Price* $3.

This is the fourth edition since 1923, with revisions to meet present needs. It is based on the industrial experience of a group of Houghton engineers. The major portion of the book is devoted to iron and steel, only one chapter covering briefly the extraction of various nonferrous metals from their ores. The chapters on iron and steel metallurgy deal with all phases, from ore extraction through manufacturing processes, including various heat-treating and hardening processes. Particular attention is given to carburizing—steels used for carburizing, carburizing materials, equipment and control, selective hardening, a general discussion of difficulties and how to overcome them, and liquid salt baths. Opening chapters deal with the physics and chemistry of metallurgy, a comparative discussion of ores, fuels, and refractories. The book concludes with a chapter on the heat-treatment of aluminum alloys and general information and data.

1944 Plastics Catalogue

Published by Plastics Catalogue Corp., 122 E. 42nd St., New York 17, *N. Y.* 1,000 *pages*, 8½x11 *in., red clothboard covers. Price* $6.

Informative and authoritative source of data material on all types of plastic materials, processing and allied subjects that will prove useful as reference for engineers interested in plastics. Each type of plastic material is covered in a separate chapter which details manufacture, forms available, methods of fabrication and typical applications. Extensive information is included on chemistry of plastics and all necessary machinery and equipment. Of particular interest are the charts on identification properties, chemical formulas, manufacture, coatings and synthetic rubber.

Maintenance Arc Welding

Published by the James F. Lincoln Arc Welding Foundation, P. O. Box 5728, *Cleveland, Ohio.* 234 *pages*, 5½ x8½ *in., flexible brown covers. Price* 50 *cents.*

Maintenance Arc Welding is the second volume developed from the 1940–42 Industrial Progress Award Program. It comprises 25 of the most significant award papers dealing with reclamation of broken or worn parts. A wide variety of industries and applications are described to show the value of arc welding in repair and fabrication of replacements.

Fundamentals Of Vibration Study

R. G. MANLEY. 128 *pages*, 5½x8½ *in., red clothboard covers. Published by John Wiley & Sons, Inc.*, 440 *Fourth Ave., New York* 16, *N. Y. Price* $2.75.

This volume has been written for those who are beginning the study of vibrations. No previous knowledge of differential equations is assumed. A series of notes in the appendices, which comprise about a fifth of the book, presents and explains the mathematical procedure which is required to apply the basic theory of vibrations and to understand the associated physical phenomena. The subject matter deals with undamped and damped motion with different degrees of freedom, effective inertia and dynamic stiffness, heavy shafts and beams, and complex vibrations. Problems are included with each chapter to provide exercise in applying the principles set forth in the text.

Bulletins

Magnetron Oscillator For Instruction and Research In Microwave Techniques

J. TYKOCINSKI TYKOCINER *and* LOUIS R. BLOOM. *Engineering Experiment Station Circular Series No.* 48. 30 *pages*, 6x9 *in. Published by the University of Illinois, Urbana, Ill. Price* 40 *cents.*

The investigation described is a continuation of experimental studies in the field of microwave technique in the ultra-high frequency ranges. Sufficient details are included to enable investigators to build a microwave oscillator, for wavelengths from 6 to 17 cm. (5,000 down to 1,700 megacycles), for use in the research laboratory. The oscillator consists of a split-anode magnetron inserted between the pole pieces of a magnet, the housing of which serves to couple the magnetron oscillating circuit to various types of transmission systems. By mounting the oscillator on a turntable, either upright or horizontally, the radiating beam can be swept either in the plane of polarization or perpendicular to it.

1943 Symposium On Powder Metallurgy

Published by American Society for Testing Materials, 260 S. Broad St., Philadelphia 2, *Pa.* 60 *pages*, 6x9 *in., cream paper covers. Price* $1.

Seven technical papers and extensive discussion comprising the symposium presented at the A.S.T.M. 1943 spring meeting in Buffalo are presented in this booklet. The papers cover fundamentals necessary to apply powder metallurgy, effect of pressure on the properties of compacts, effect of particle size, alloy powders, metal powder friction materials, hot-pressing of metal powders and the influence of homogenization on the physical properties of copper-nickel powder alloys.

Manufacturers' Publications

Hydraulic Pump—Hub Industries, Inc., 38-04 48th St., Long Island City 4, N. Y. Pamphlet, 11 pages. Details and features of the Live Line hydraulic pressure converter are explained by means of transparent plastic sheets, followed by a discussion of theory and operation.

Transmissions—D. O. James Mfg. Co., 1140 W. Monroe St., Chicago, Ill. Catalog No. 1000R, 376 pages. Various types of speed reducers, gear reducers and flexible couplings are described from the standpoint of solving transmission and gear reduction problems.

Control—Taylor Instrument Companies, P. O. Box 110, Rochester 1, N. Y. Bulletin No. 98159, 8 pages. Covers uses and operating principles of the Fulscope Pneumatic Set controller.

Fasteners—American Institute of Bolt, Nut & Rivet Mfrs., 1550 Hanna Bldg., Cleveland 15, Ohio. Periodical, 24 pages. First number of "Fasteners," containing engineering articles and other information of interest to those who have fastener problems.

Rotary Pumps—Blackmer Pump Co., Grand Rapids 9, Mich. Bulletin No. 304, 6 pages. Describes and illustrates design and operational features of company's line of pumps.

Rings—Reliance Spring Washer Div., Eaton Mfg. Co., Massillon, Ohio. Folder No. 43, 6 pages. Gives general data by means of lists and drawings regarding standard retainer rings for bearing, housing and shaft applications.

Rivets—Cherry Rivet Co., 231 Winston St., Los Angeles, Calif. Manual B-44, 36 pages. All features of the company's blind rivet are covered, including selection, with text, tables and illustrations.

Heat-Treatment — A. F. Holden Co., New Haven 8, Conn. Bulletin 110, 28 pages. Results obtained with neutral baths for hardening and tempering are presented.

Friction—Meehanite Research Institute of America, Pershing Sq. Bldg., New Rochelle, N. Y. Bulletin No. 17, 8 pages. Results of research into the galling, seizing and scuffing of metal surfaces in contact with one another is presented.

Aluminum — Aluminum Company of America, Pittsburgh, Pa. Catalog, 60 pages. Screw machine products made of aluminum alloys and used as fasteners are listed along with dimensions and weight tables.

Lighting Accessories — Appliance & Merchandising Dept., General Electric Co., Bridgeport, Conn. Catalog, 16 pages. Illustrates and describes all types of accessories for fluorescent lighting and includes mounting diagrams and results of tests.

Arc Welding—Hobart Bros., Troy, Ohio. Design Sheets. Another group of eight pages to be added to the series on "Practical Design for Arc Welding."

Torque Converters — Hydraulic Div., Twin Disc Clutch Co., Rockford, Ill. Bulletin No. 135, 16 pages. Function, operation and installation of hydraulic torque converters are explained in detail.

Timers—Automatic Temperature Control Co., 34 E. Logan St., Philadelphia 44, Pa. Catalog B7, 4 pages. Describes Series 2400 cam timers, with one page devoted to design features.

Plastic Tubing—Irvington Varnish & Insulator Co., Irvington, N. J. Catalog, 16 pages. Product data sheets describe characteristics and applications of various types of Fibronized extruded plastic tubing and insulation markers.

Springs—Dunbar Bros. Co. Div., Associated Spring Corp., Bristol, Conn. Handbook, 106 pages. Charts, formulas and other pertinent data relative to the engineering and design of mechanical springs are included.

Safety—E. I. du Pont de Nemours & Co., Wilmington, Del. Bulletin, 16 pages. Explains the company's proposed safety color code for industry.

Plastics—Plastics Dept., General Electric Co., 1 Plastics Ave., Pittsfield, Mass. Bulletin, 20 pages. Describes facilities for making plastic products and illustrates examples.

D. C. Motors—Century Electric Co., 1806 Pine St., St. Louis 3, Mo. Catalog 3421, 12 pages. Illustrates and describes features of d. c. motors ranging from 1/6 to 300 hp.

Thermocouples—Wheelco Instruments Co., Harrison and Peoria Sts., Chicago 7, Ill. Bulletin S2-4, 36 pages. Describes thermocouples and accessories and gives data on selection of thermocouples, lead wire, protecting tubes, heads and insulators.

Packaging — Sherman Paper Products Corp., Newton Upper Falls 64, Mass. Manual. Methods of packing according to government specifications, with emphasis on new methods to speed packing production, are shown in detail, along with samples of packaging materials made by the company.

Moisture Indicators — Chandler-Evans Corp., South Meriden, Conn. Bulletin, 4 pages. Describes Protek-Plugs, made from transparent plastic, that contain silica gel to absorb moisture and thus protect highly machined surfaces during transportation and storage.

Trap—W. H. Nicholson & Co., 12 Oregon St., Wilkes-Barre, Pa. Bulletin 341, 2 pages. Presents details of Model JR weight-operated trap for automatically draining water and oil from compressed air devices.

Immersion Coatings—Enthone Co., 442 Elm St., New Haven 2, Conn. Bulletin, 8 pages. Processes for blackening copper and copper alloys, iron and steel, and zinc and zinc alloys are described and uses are indicated.

Latches—I-T-E Circuit Breaker Co., 19th and Hamilton Sts., Philadelphia 30, Pa. Bulletin 4312, 4 pages. Reprint of article on rapid-release latches from PRODUCT ENGINEERING for Nov., 1943, with special introduction.

Connectors—Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, Calif. Catalog, 24 pages. Various connectors for storage batteries are described and application photographs and condensed data sheets are included.

Induction Heating — Ohio Crankshaft Co., 3800 Harvard Ave., Cleveland 1, Ohio. Booklet, 32 pages. Sixteen case histories of results obtained with Tocco induction heating are featured.

Hydraulic Pumps—Pesco Products Co., 11610 Euclid Ave., Cleveland 6, Ohio. Bulletin 4, 28 pages. Performance of aircraft applications of hydraulic pumps and related equipment are presented for the benefit of product designers who may want to use such equipment in other applications.

Fasteners—Cleveland Cap Screw Co., 2917 E. 79th St., Cleveland 4, Ohio. Catalog F, 36 pages. Dimensions and weights of screws, bolts, nuts, pins, studs and washers made by the company are listed.

INVASION *and the* FINAL CHALLENGE

The idea that our national security some day would depend upon the successful invasion of continental Europe by our armed forces was inconceivable to the average American but a few short years ago. Yet, today our whole strength is assembled to that very action and for assuring a sound and permanent peace.

America became great without aggression . . . without tyranny. Our greatness has been achieved without destroying others . . . ours is a history of unprecedented industrial progress, of development of our own resources and reliance on our own efforts.

Aggression is foreign to American philosophy. Yet, today we find ourselves faced with the choice of destroying or being destroyed. Today we are confronted by the hard fact that the kind of peace which we all so fervently desire can be achieved only by crushing autocracy and by removing the causes of aggression.

We are now engaged in the accomplishment of the first objective. Since Pearl Harbor a complacent, peace-loving America—the largest of the "soft" and "decadent" democracies—has grown strong and tough. Out of the inherent virility of a free people we have moulded the mightiest force for invasion and attack that the world has ever seen.

We have reached our peak rates of war production. We are producing as much war equipment as all the rest of the world combined.

History will record our industrial mobilization as a phenomenal achievement.

The battle of production has been won!

The full might of our armed forces and those of our allies unleashed against the Axis war machine will bring eventual victory. Two and a half years of intensive preparation, backed by 168 years of growth as a free nation, has given us superiority over twenty years of painstaking preparation by the totalitarian and militaristic countries with their enslaved peoples.

Every American has contributed toward this powerful offensive. Our manufacturers and business leaders have exerted their fullest efforts. Our industries have mobilized their tremendous resources—tapped to the fullest degree their inventive and productive genius. The men and women in the factories, on the farms, and in the mills and mines have played a magnificent

part in the tremendous production program. Citizens all are making their contribution to the armed victory that lies ahead

We have demonstrated that a free people under a free enterprise economy can unite in a common purpose.

* * *

When the war is won, we shall be faced by our second objective . . . removing the causes of aggression. This is a social challenge. A challenge to those who would sacrifice our democratic way of life for personal gains or foreign ideologies.

The best insurance for the continuance of our democracy is a successful democracy. That means a dynamic and not a static democracy. All of us who want to preserve the ideals that have made America . . . and that includes all but a handful of extremists . . . must determine to find the policies and programs which will permit us to make the most of the abundance nature has provided for us.

To achieve this end we must recognize the fact that we are but a wheel in the machinery of world economy. A wheel that must drive or be driven. A wheel that must mesh smoothly with the many other wheels or be stripped of its cogs.

We are the only nation on earth free enough and strong enough to shape the mould of its own destiny. We can be hampered by nothing but our own confusion.

* * *

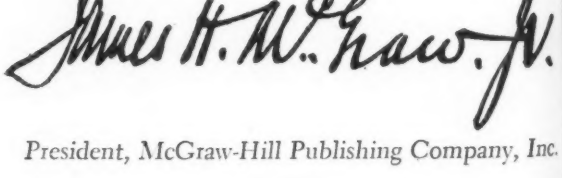
The mind and the heart of all America today brood over the shores of Britain and watch over the narrow waters that wash the beaches of the Continent. And the prayers of all America go with each of those who embark upon that epic passage.

Those of us at home who are producing the fighting tools and who are so earnestly concerned with the problems that will face a postwar America, should see now, even if we may never have seen it before, that all our plans will be worth just exactly what the men and women who make that passage are prepared, competent, and inspired by their leadership to make them worth.

For those men and women are America!

They have gone out from rich homes and poor homes alike, from farms and factories, from schools and churches, from mines and ranches, from offices and studios, to take their places in the battle line. They are a cross-section of the America that is to be.

Whoever may draw the plans for that America, it is those men and women who will make the plans good. Invasion is their first step toward that end. May their work be speedily done, and may our plans be worthy of that work.

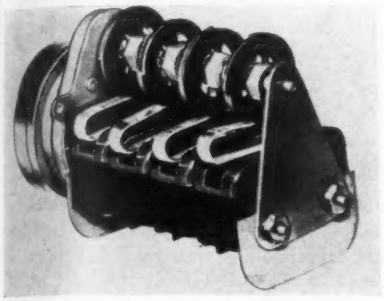


President, McGraw-Hill Publishing Company, Inc.

NEW MATERIALS AND PARTS

Repeat-Cycle Timer

Available with from one to eight switches, as required, the Series 5800 continuous-running repeat-cycle timer operates on either a.c. or d.c. Motor speed is selected according to the timing cycles desired. Most speeds range from 8 r.p.m. down to one revolution



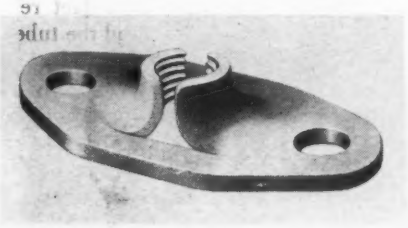
per month. However, adjustment to one revolution in six months is possible. Precision snap switches are used, single or double throw, 10-amp. capacity at 110 volts a.c. The 4-circuit assembly illustrated shows adjustable cams which can be set to throw the switch from 1 to 180 deg. of the revolution. Specially cut cams are also available for various combinations of "on" and "off" cycles covering a range of from more than one accutation per sec. down to one per month. These timers are available for various commercial a.c. voltages and frequencies as well as d.c., the motors featuring sealed-in lubricated gear trains. They are also available with brake for instant stop, if desired. Haydon Mfg. Co., Box 52, Forestville, Conn.

Constant-Level Lubricator

Automatically controlled visible oiling for most types of bearings is offered by the Type J constant-level lubricator. When the reservoir is full, only enough oil is released to bring the level in the bearing oil well to the oil-level line on the base of the lubricator. When the bearing oil level falls, air is admitted into the reservoir through a vent, automatically releasing enough oil to restore the level. Construction of the lubricator consists of the base, dome, and reservoir. In the base are a bottom and side outlet for connection to bearings, either or both of which may be used. In the center is a large air intake opening which can be connected to a filter, if necessary, or to a breather tube on the bearing. The dome maintains the oil level at its lower edge and acts as a stopper or valve to prevent spilling of oil in filling or removing the reservoir, which is sealed to a collar with plastic cement. Separate passages for air and oil are provided. The lubricators are available with capacities of 2, 4, 8, and 16 oz. Oil-Rite Corp. 3482 S. 13th St., Milwaukee 7, Wis.

Vibration-Resistant Fastening

Conforming to AAF Specification No. 25531, the Hi-Stress Speed Nut is a one-piece unit that is interchangeable with nut plate AN362 for high-temperature applications in all structures. The fastening has a low installation torque and the self-locking feature is retained after many removals. The fastening is identified by No. A6103H-1032. Tinnerman Products Inc., 2041 Fulton Rd., Cleveland 13, Ohio.

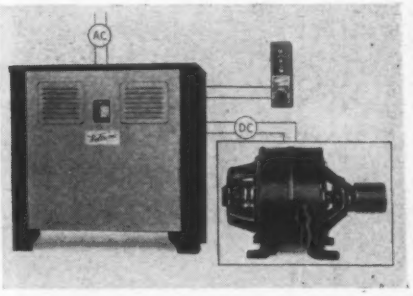


Metal-to-Glass Seal

Iron-cobalt-nickel alloy, known as Kovar, is available in rods, wire, tubing and sheet form, or in special fabricated shapes. Alloy when heated bonds itself chemically to glass parts to form a hermetic seal. Metal-to-glass joint is vacuum and pressure tight under varying conditions of pressure, temperature and humidity, thus eliminating cementing and gasketting arrangements. Kovar-sealed assemblies can be soldered, welded or brazed to metal parts or containers. The alloy has been used for several years to carry electrical conductors through the housings or walls of electrical devices. Stupakoff Ceramic & Mfg. Co., Latrobe, Pa.

Electronic Drive

D. c. motor performance from a.c. power without requiring special motors is provided by a line of adjustable-speed electronic motor drives. The self-contained units are applicable to any machine driven by a d.c. shunt motor. Electronic rectifier tubes are used to



convert a.c. to d.c., supplying separate power to the d.c. motor armature and field circuits. Each circuit is individually controlled through other electronic tubes, The method used to control armature current prevents excessive current ripples. Full field strength of the motor and limited armature current is utilized in starting. Full torque can be provided at low speeds. For speeds greater than the basic speed of the motor, maximum horsepower is available. If the motor stalls because of overloading the control automatically limits the current drawn. On restarting, the motor rises to the

selected speed without further adjustment. In addition to the start, stop and speed selection controls of standard units, reverse can be supplied, with or without an independent speed-selection control. Dynamic braking, dual-control stations, limit switches or sequence and time controls can be used. Units can be wall or floor mounted. External transformers are not required. Control station can be mounted on the machine or at any location handy to the operator. Standard capacities are available from ½ to 3 hp., single phase and 5 to 10 hp., three phase. Other sizes or special designs for specific applications can be supplied. Standard voltages are 220/440 at 60 cycles, 550 volts, but 25- or 50-cycle machines are available. Weltronic Co., 20735 Grand River, Detroit 19, Mich.

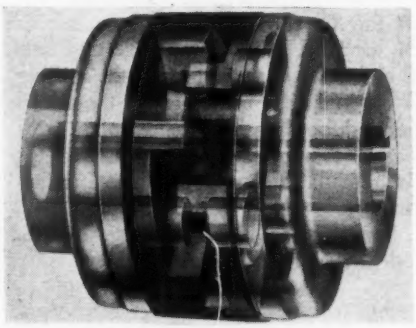
Precision Filter

Large capacity, fineness of filtration, light weight and design simplicity are combined in the Micronic filter, so designated because it filters particles of 5 microns and larger. The unit operates from —65 deg. F. to 165 deg. F. The filtering cartridge expands and contracts with variations in temperature. An automatic pressure relief bypasses the full flow of liquid at any predetermined pressure setting if line surges should pass a safe peak. The filter operates in any position. Dural is used for the metal

parts, although other alloys can be supplied for special applications. The model illustrated measures 6 x 8½ in., weighs 2 lb. and has 3,800 sq.in. of filtering area. Rated output is 1,800 gal. per hr. at 100 deg. F. with pressure drop of 16 oz. filtering AN-VV-O-366a hydraulic fluid. Inlet opening has 1½ in. dia. Filtering flow can be arranged for either direction. Other sizes available are 2 and 4 in. with capacities of 450 and 900 gal. per hr., respectively. Adel Precision Products Corp., Burbank, Calif.

Flexible Coupling

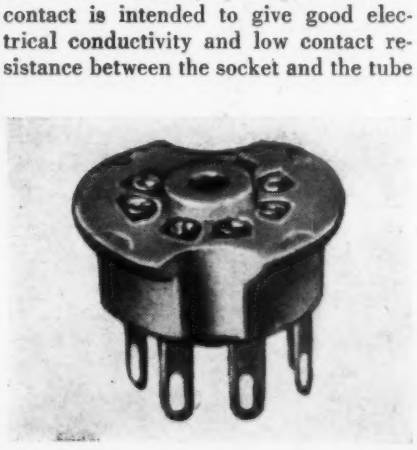
To compensate for angular and parallel misalignment, the Multiflex coupling can be had for special or custom-made applications in addition to normal applications. The unit features a rubber center member made up of two driving specially constructed metal parts bolted



into the rubber and spaced to distribute the load evenly throughout the flexible centers. This results in the coupling being suitable to withstand angular and parallel misalignment together with shock loads in any direction. The flexible element is cushioned in water- and oil-resistant rubber. No lubrication is necessary. Units are available in horsepower ratings at 100 r.p.m. from 0.15 to 60. Dimensions vary from 1⅞ to 12½ in. dia. and 1¾ to 13½ in. length. Automatic Machine & Tool Co., 132 Charles St., Auburndale, Mass.

Miniature Tube Socket

Developed for long life under regular service conditions, a miniature tube socket includes a specially designed Micro-Processed beryllium copper contact that is heavily silver-plated. This contact is intended to give good electrical conductivity and low contact resistance between the socket and the tube



pin. It is available in two types: Low loss with Navy Grade G steatite casting having loss factor of 0.016 or less and capacity of 1.5 micromicrofarads or less at 10 megacycles; and general purpose with mica-filled plastic casting having a loss factor of 0.05 or less and capacity of 3 micromicrofarads or less at 10 megacycles. Hugh H. Eby, Inc., 18 W. Chelten Ave., Philadelphia 44, Pa.

Metal Adhesive

Known as Fix-Iron, an adhesive can be used for joining such metals as iron, steel and brass in addition to wood. It is available in powder form and mixed with water as used. No heat is required. It is applied with a knife, or can be hammered into cracks. After hardening, the adhesive is said to have the same expansion and contraction properties as iron. So-Lo Works, Loveland, Ohio.

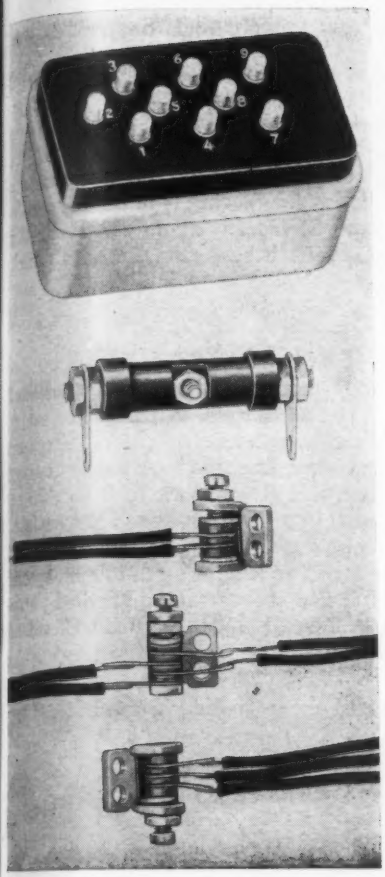
High-Frequency Probe

For convenience and efficiency, especially at high frequencies such as those encountered in frequency modulation and television design and test work, a cone-shaped probe, with the "high" terminal in its nose, is part of the wide range vacuum-tube voltmeter. Placing the "high" terminal in the nose permits close inspection of the circuit. The probe is molded from low-loss material. Voltmeter Model VM-27E is illustrated with the probe connected to the input circuit

of an experimental frequency-modulation receiver. Because the probe is attached to a 4-ft. cable the voltmeter proper can be placed in a convenient position on the test bench. Alfred W. Barber Laboratories, 34-02 Francis Lewis Blvd., Flushing, N. Y.

Copper-Oxide Rectifiers

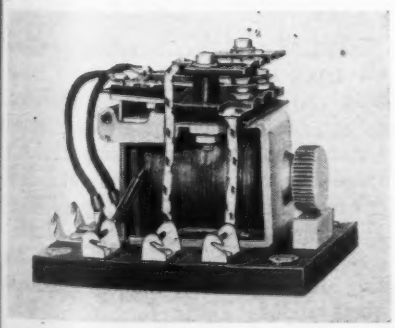
Known as Coprox, a group of copper-oxide rectifiers has gold contacts on the copper-oxide "pellets," adaptable mountings and presoldered lead wires or other arrangements to prevent overheating during assembly of equipment. BX-100, a center-tap, full-wave rectifier, is in-



closed in phenolic plastic and rectifies high-frequency current operating in special circuits up 8 megacycles. BX-22.3 is a double-bridge rectifier with notable temperature and temperature-current characteristics. BX-22.5 is a single half-wave, BX-22.2 a full-wave and BX-22.4 a double half-wave unit. Low forward resistance combined with high leakage resistance are additional features. Bradley Laboratories, Inc., 82 Meadow St., New Haven 10, Conn.

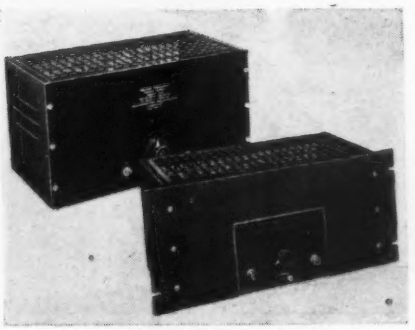
Adjustable Overload Relay

For overload protection in circuits with varying current demand the Series 445-G-33393 relay can be adjusted to close at any value from 0.200 to 0.750 amp. by means of an adjustable core which varies the reluctance of the magnetic circuit. Contact combinations up to 3 pole, double throw are available with contact rating of 5 amp. at 115 volts, 60 cycles. Coils can be wound to operate on current or voltage ranges where minimum wattage is over 0.32 and maximum wattage is under 4.5. Resistance is 8 omhs and temperature rise is 52 deg. C. at 0.750 amps. Vibration resistance is rated at 8 G., energized or deenergized. Insulation is ground tested at 900 volts a.c. Dimensions are 1⅞ x 2⅜ x 2⅞ in., and weight is 9 oz. Gardian Electric, 1621 W. Walnut St., Chicago, Ill.



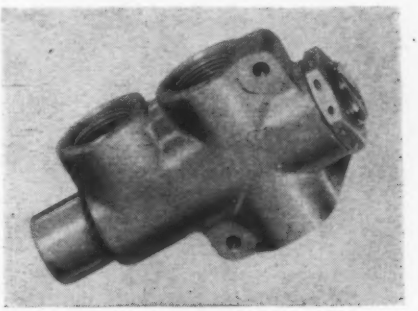
Voltage Regulator

Differing only in construction, a voltage regulator is available as Model 1100 for table use and as Model 1110 for rack mounting. Both units use the series regulator circuit. Low noise level and better regulation are provided by a high-gain two-stage control circuit. High-voltage output can be shifted through a range of 225 to 325 volts by a potentiometer control on the front panel. Maximum current drain is 200 milliamperes from 225 to 300 volts and 180 milliamperes from 300 to 325 volts. Under these conditions the sum of all a.c. components present in the output is less than 5 millivolts. The change in voltage output from no load to full load is less than 1 volt. Primary of the power transformer is tapped for use at 105, 115 and 125 volts on a 50- to 60-cycle source. An unregulated heater supply winding of 6.3 volts at 5 amp. is furnished. Communication Measurements Laboratory, 116 Greenwich St., New York, N. Y.



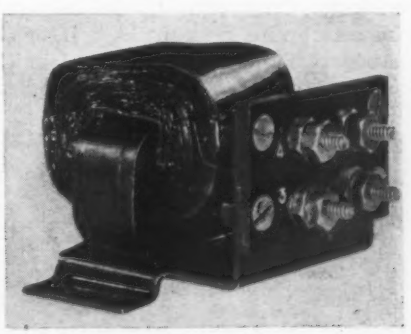
Adjustable Relief Valve

Particularly adapted for aircraft high-pressure hydraulic systems where smooth operation and long life at maximum flow are necessary, an adjustable-pressure relief valve has a body made of an aluminum forging with an inner casing of stainless steel. Introduction of the dashpot is said to improve operation and eliminate vibration and chattering when the pressure is balanced against the spring. AN-62-27 packing rings are used and the valve is intended for operation in temperatures ranging from —65 deg. F. to 165 deg. F. The valve is available in three sizes. VR-5 has port threads ¾–18, cracking pressure of 500 ± 10 lb. per sq.in., pressure range from 300 to 800 lb. per sq.in. and full flow of 575 lb. per sq.in. VR-6 has port threads ⅞–18, cracking pressure of 1,250 ± 10 lb. per sq.in., pressure range from 700 to 1,300 lb. per sq.in. and full flow of 1,350 lb. per sq.in. VR-1 has port threads ¾–18, cracking pressure of 1,250 ± 10 lb. per sq. in., pressure range from 700 to 1,300 lb. per sq.in., and full flow of 1,350 lb. per sq.in. American Screw Products, 7000 Avalon Blvd., Los Angeles, Calif.



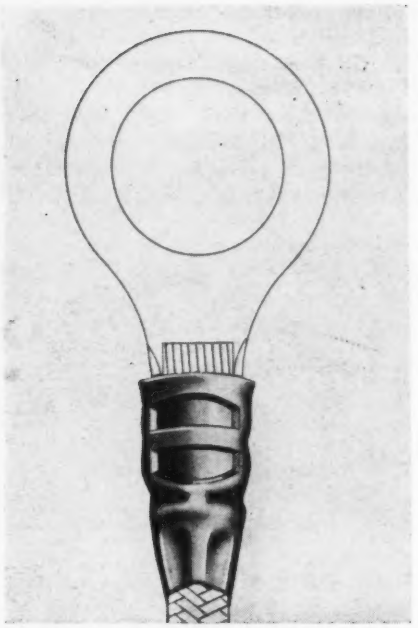
Aircraft Transformer

Intended for use in aircraft applications, a transformer for lighting systems weighs 8 oz. and has a temperature rise of 30 deg. C. This permits operation over ambient temperatures from —65 deg. C. to 70 deg. C. and at altitudes up to 50,000 ft. For special applications the output voltages and currents can be varied without affecting size and weight if output is held to 30 volt-amperes. New York Transformer Co., 24 Waverly Place, New York, N. Y.



Pre-Insulated Terminals

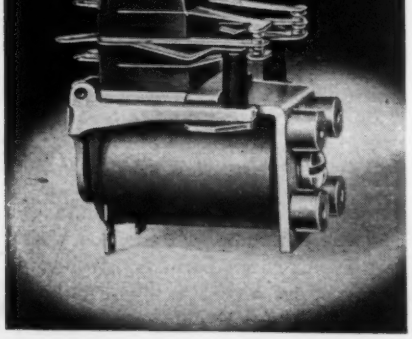
Designed for mass production, a pre-insulated terminal for solderless wiring has the insulation permanently bonded to the copper of the terminal and provides identification for the wires. Red



terminals are used for wire sizes 22 to 18 and blue for wire sizes 16 to 14. In production the terminals are crimped with precision installation dies. Aircraft-Marine Products, Inc., 1591-A N. Fourth St., Harrisburg, Pa.

Telephone-Type Relay

Developed for maximum magnetic efficiency with resultant sensitive operation at minimum power input the Model TKL telephone-type relay was specifically designed for high-frequency use. It incorporates Mycalex insulation, but can be supplied with approved Bakelite insulation for standard switching service. The coil is sealed with cellulose acetate. The relay meets standard salt-spray specifications and withstands shock and vibration to 10 G. Standard contacts are of palladium, but fine silver or special alloy contacts are available. Double pile-ups of contacts can be supplied from single A, B, or C arrangements to a maximum of four C combinations. Weight, less contact pile-



ups, is 1.5 oz. and dimensions are 1 7/16 x15/16x1 1/16 in. Special tapped studs are brazed to the frame for mounting and prevent short circuits. Allied Control Co., 2 East End Ave., New York 21, N. Y.

Special Capacitor

Built for a special application of the electron microscope, a capacitor has a rating of 0.01 microfarads at 40,000 volts d.c. Other features include continuous operation at 80 deg. C. and withstanding of submersion and heavy surges. The case is welded steel $4\frac{11}{16}$x $5\frac{3}{4}$x7 in., and a Westinghouse solder-

seal standoff insulator $8\frac{1}{2}$ in. high is soldered directly to the case. Industrial Specialty Co., 1725 W. North Ave., Chicago 22, Ill.

Laminated Plastics

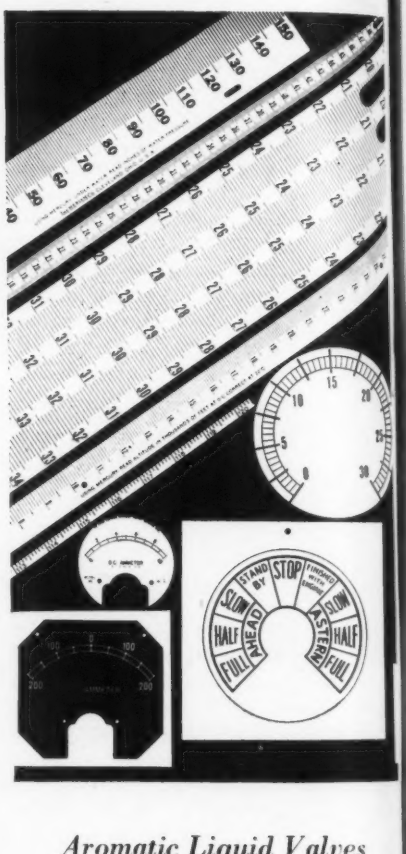
Consisting of layers of fabric or paper impregnated with a specially formulated phenolic resin, Panoform laminated molding materials are furnished in sheets that are formed and cured under heat and low pressure. Sheets up to 48x60 in. and from 1/16 to $\frac{1}{8}$ in. thick are available. They are formed over inexpensive wood or metal molds or dies and are especially suited for small runs. Sharp-angle bends and compound curvatures can be made. Pressure used ranges up to about 250 lb. per sq. in., depending on thickness of the material and the shape and curvature of the piece. For forming, the Panoform sheet, rather than the mold, is heated in an oven, under infra-red lamps or by dipping in hot oil. Black or natural are the only colors available at present. Panelyte Div., St. Regis Paper Co., 230 Park Ave., New York, N. Y.

Rope Clamps

Four new sizes have been added to the line of Safe-Line clamps for wire rope. Stock sizes are now available for rope with diameters ranging from $\frac{1}{16}$ to $\frac{3}{4}$ in. Patented feature of Safe-Line clamps is the inside grooving to fit the rope. Safe-Line Clamp Div., National Production Co., 4561 St. Jean Ave., Detroit 13, Mich.

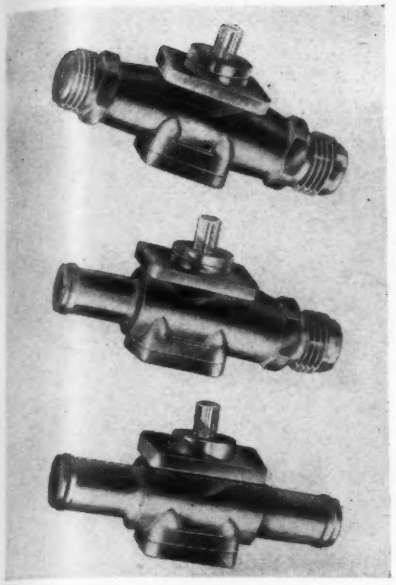
Scale Marking

By means of the recently perfected Syl-o-ette process, markings for scales, dials, templates, indicators, diagrams and other precision work are reproduced from master art work with notable accuracy on plain or coated flat surfaces such as metal and plastics. In addition to standard lengths up to 100 in., special sizes and shapes can be handled. Maymer Corp., 10874 Berea Road, Cleveland 2, Ohio.



Aromatic Liquid Valves

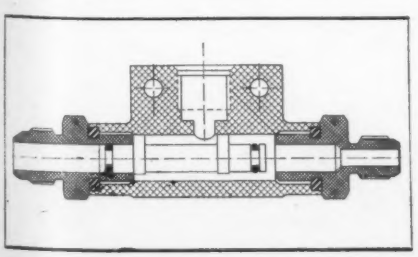
Volatile liquids are handled by three new types of aircraft fuel-line Arrowmatix valves. They are lever operated, but can be installed for either manual or remote control. By making the AN thread integral with the body the danger of cracking the valve body by overtightening during assembly is eliminated. Weight is kept to a minimum by using aluminum alloy. Smooth anodized linings reduce vapor formation. The



valves will operate under temperature conditions ranging from −65 deg. F. to above fuel boiling points. Maximum initial breakout torque ranges between 12 and 18 in. lb., but 6 in. lb. is sufficient to open or close the valve after breakout. The handle operates on a 90 deg. turn to either "on" or "off," with a spring detent at both positions. The valve is available in three types, with ends to customers specifications: AN-816 threads at each end, AN-816 threads at one end and 1-in. hose fitting at the other, or 1-in. hose fittings at both ends. The valve is AN flange mounted. Operating pressures up to 50 lb. can be handled. Dimensions are 6½ in. long by 2½ in. deep. Sizes available are ¾, 1, 1¼ and 1½ in. Davidson Mfg. Co., 5142 Alhambra Ave., Los Angeles 32, Calif.

Shuttle Valve

No springs and only one moving part are used in a shuttle valve fabricated of aluminum with the exception of four toroid seals. The valve comprises a body, two ends and a shuttle. There are three ports. In normal operation oil flows through one end and out the center port. In emergencies or when additional pressure is required, compressed air is released through the opposite end and out the center part, at the same time closing the oil entrance port. Electrol, Inc., Kingston, N. Y.

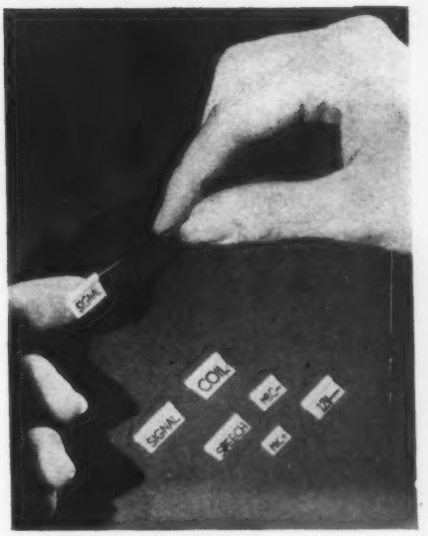


Beryllium Copper Wire

Silver-coated spring-grade beryllium copper wire is now available in 0.064 to 0.007-in. sizes. It has a tensile strength of 185 lb. per sq. in. after hardening. The silver coating is applied by a special process that is intended to reduce wear on coiling tools, increase surface electrical conductivity and reduce surface attack during hardening. Little Falls Alloys, Inc., 189 Caldwell Ave., Paterson, N. J.

Drawing System

Axonometric projections are made to scale with the Air-Vu drawing system and the Sun-Vu projection drawing machine. A special triangle and pair of dividers, shown on the drawing board at the right of the machine in the illustration, are used in the former, one of the chief uses of which is to make projections of objects from two-dimension drawings. Phantom and exploded views are also made in this manner. The machine is used for illustrating finished objects. The part or assembly is mounted as shown. The operator follows the outline of the object, including significant details, through the viewer which has crosshairs. As he follows the outline the operator presses a button, between the wheel controls, which operates a solenoid in the head of the marker at the right. The solenoid operates a plunger that marks a point on the drawing paper. These points are then connected, using the Air-Vu instruments. The angle at which the object is viewed and reproduced is the same as that used in the special triangle. This angle, known as the angle of "unity," produces a projection that has no vanishing points. Air-Vu Co., 1742 Arapahoe St., Denver 2, Colo.

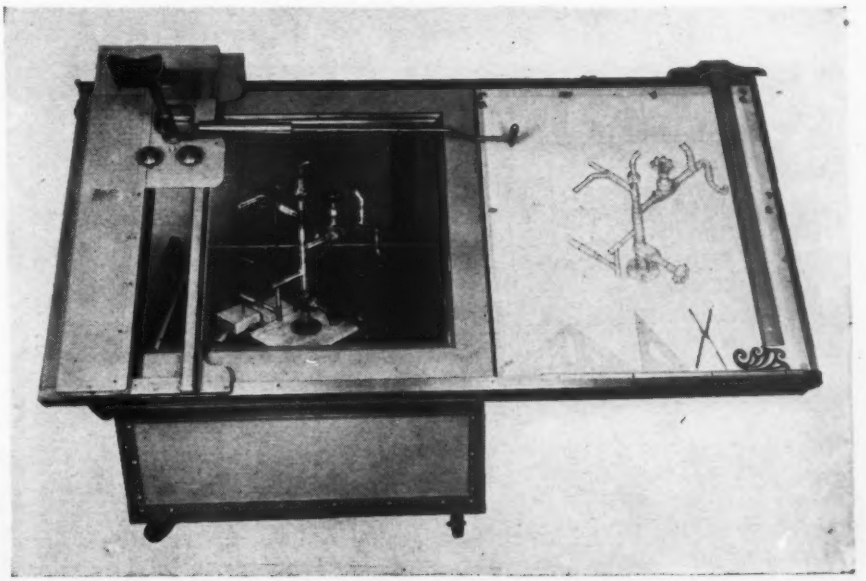


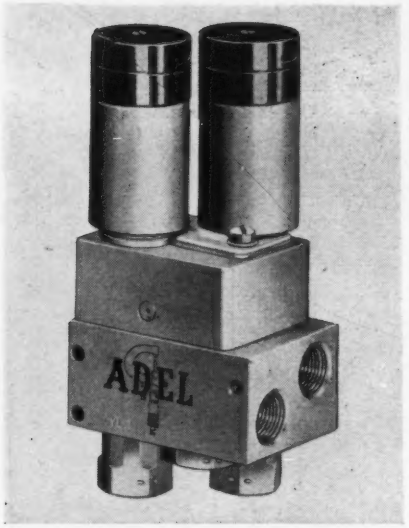
Wire Markers

Tabs for Turbo apron-type identification markers for small-diameter wires are intended to provide sufficient area on which to imprint adequate identification markings. The markers have the resistant properties of standard varnished-cotton tubing. William Brand & Co., 276 Fourth Ave., New York, N. Y.

Hydraulic Selector Valve

Light weight, accelerated action and low current consumption are features of a solenoid-operated 4-way hydraulic selector valve designed for aircraft installations located some distance from the flight station. Length of hydraulic lines is reduced and weight is saved. Current of 12 amp. at moment of impulse automatically drops at completion of stroke to holding pull of 0.2 amp. at 24 volts d.c. The body is fabricated from dural bar stock. Steel puppets





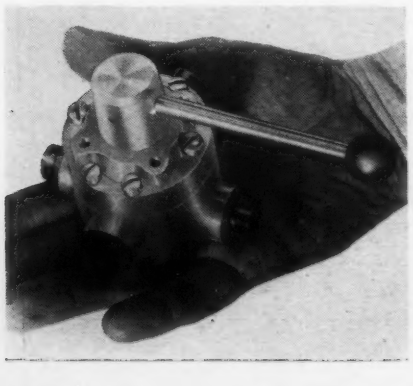
have replaceable steel seats. The shaft is furnished for manual operation. Electrical connections for either 2-wire or 1-wire and ground circuits are provided. Terminal posts are protected by plastic caps. The unit, which withstands both continuous duty and rapid cycling, measures 2⅝x2⅞x7 $\frac{3}{16}$ in. and weighs 4.1 lb. It operates at pressures up to 1,500 lb. per sq. in. Adel Precision Products Corp., Burbank, Calif.

Urea-Resin Glue

Designated 8-9XC-U, a hot press urea-resin glue can be used straight; with a fortifier, to meet standard 3 hr. boil test; and with wheat flour of any gluten strength. Emphasis is placed on the fact that a free-spreading, uniform-viscosity glue is obtained when the formulation is used with any wheat flour, regardless of gluten strength. I. F. Laucks, Inc., 911 Western Ave., Seattle, Wash.

Hydraulic Control Valve

Although it weighs 13 oz. a hydraulic directional control value is designed to operate under a pressure of 3,000 lb. per sq. in. with a maximum handle torque of 20 in. lb. The valve is of semi-balanced poppet type. Excessive pressure in the cylinder lines caused by valve being partially open does not affect the operation and handle torque. Likewise, back pressure caused by the valve being partially open does not add to the handle torque. Because a rotary disk-type cam is used, the valve is adaptable to operation by a small electrical motor. The electrically driven unit can open in ½ sec. and is available for 24-volt, 3-amp. d.c. and 200-volt, 400-cycle, a.c. circuits. The valve is available in 3-5 gal. per min. and 6-10 gal. per min. sizes. Mounting and porting, either AN or AC, can be to desired specifications. Hydraulics, Inc., 457 S. Fair Oaks Ave., Pasadena, Calif.



Strainer Basket

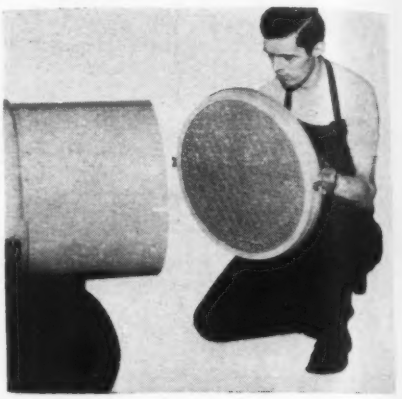
Increased straining area and rugged construction are features of a series of strainer baskets made from heavy-gage perforated sheets, available with various size openings. Use of perforated sheet increases the net straining area up to 10 times the pipe area. Part of the gain in straining area is achieved by spot-welding, and by use of heavier material. Blackmer Pump Co., Grand Rapids 9, Mich.

Lightweight Switch

Intended as a lightweight multi-circuit switch the MACO Featherweight switch has a frame molded of high-impact phenolic plastic material. Knurled inserts with ¼-in. depth of thread are provided on ⅝x1¼-in. centers and are locked in place. Newly designed hook-type soldered terminals are incorporated. Coin-silver contacts, fastened in phosphor-bronze spring leads, carry 10-amp. a.c. or 2-amp. d.c. at 115 volts. Contacts can be ganged in any number and combination. Metallic Arts Co., 243 Broadway, Cambridge, Mass.

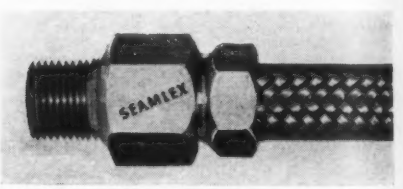
Air Filter

Designed for quick installation on all standard-type d.c. generators, an impingement-type filter unit traps dust particles before they reach rotating parts. Filter medium is a permanent type with high dust-holding capacity, low air resistance and high filtering efficiency. It is encased in an arc-welded steel frame and can be removed for cleaning. Various sizes are available. Air Devices, Inc., 17 E. 42nd St., New York 17, N. Y.



Flexible Hose Fitting

Added to the line of D.T. detachable type fittings for flexible metal hose is a ¾-in. I.D. size. These fittings consist of three parts and are said to be suitable for use at temperatures above 250 deg. F. Seamlex Co., 27-27 Jackson Ave., Long Island City, N. Y.

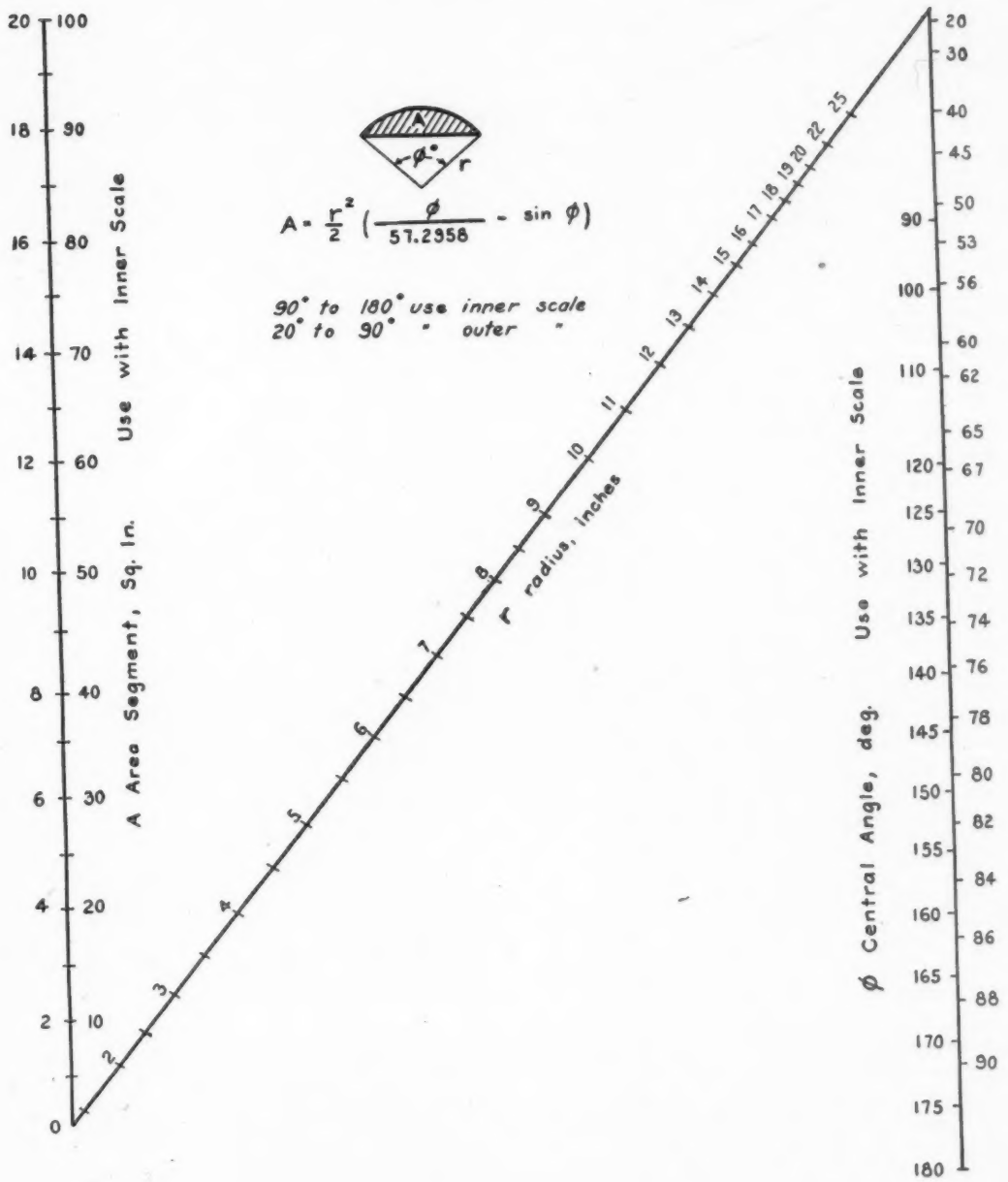


Inspection Gage

Both thread lead and diameter can be checked with the Model 1141 thread-lead inspection gage. The sensitive contact point floats laterally with the axis of the thread and sets itself between the sides of the thread. The motion of the contact is transferred to the dial indicator. This indicator is graduated to read in thousandths of an inch and the capacity of the gage will handle threads up to 1½ in. in diameter, a maximum distance between points of 2 $\frac{1}{16}$ in. and a minimum distance of $\frac{7}{16}$ in. A minimum distance of 0.156 in. can be checked by using a special attachment. Federal Products Corp., 1144 Eddy St., Providence 1, R. I.

Area of Circular Segment

CARL P. NACHOD


A = r²/2 (φ/57.2958 - sin φ)
90° to 180° use inner scale
20° to 90° " outer "
A Area Segment, Sq. In.
Use with Inner Scale
r radius, inches
φ Central Angle, deg.
Use with Inner Scale

THIS nomogram has two ranges and is constructed from the exact formula for the area of a segment.

A = area of segment
r = radius of the circle
ϕ = central angle subtended by segment, deg.

$$A = \frac{r^2}{2}\left(\frac{\phi}{57.2958} - \sin\phi\right)$$

Area A increases directly as the square of the radius r, and also directly as the difference between the arc ϕ of the central angle and its sine. For angles of ϕ less than 20 deg., the area A is very small.

The chart has a common graduated diagonal for r. Any computing secant drawn through the diagonal and through the vertical scales satisfies the equation.

For angles between 20 and 90 deg., the outer graduations on both vertical scales are used. For angles between 90 and 180 deg., the inner graduations on both vertical scales are used. For areas of segments having arcs greater than 180 deg., use the supplement of 360 deg. for the central angle and subtract the area as given by the nomogram from the area of the complete circle.

Length of Circular Arc

CARL P. NACHOD

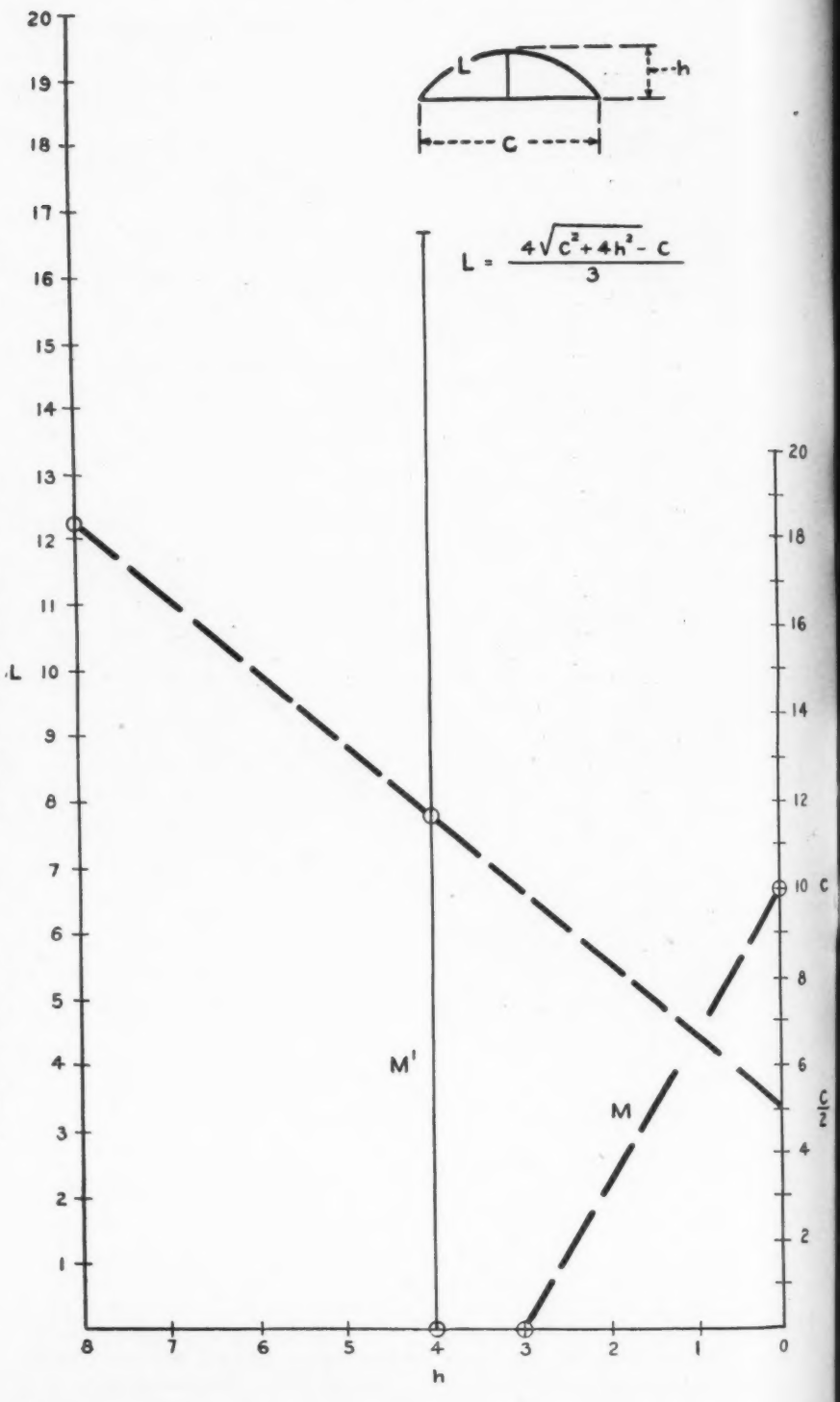
A FORMULA, given by Wm. W. Johnson, for finding the length of arc L, having given the chord c and the maximum rise or height of the arc h over the chord, is

$$L = \frac{4\sqrt{c^2 + 4h^2} - c}{3}$$

Although this formula is approximate, it is accurate to three places for chords up to one-third of the circumference, or when h/c equals 0.3 or less.

The accompanying nomogram has been constructed for the solution of this equation. To show how the nomogram is used, let the problem be to find L when c equals 10 and h equals 3. The procedure is as follows: Draw the line M connecting 10 on the c scale with 3 on the h scale, and lay off the length of line M from the base of the blank M' scale. Through one half of 10 on the c scale, and through the point on M' just determined, draw a line to intersect with the L scale. The required value of L, or 12.27, is the point of intersection.

The computing secant must always pass through one-half the value of c. The nomogram is of course true when all three variables are multiplied or divided by the same number, as by 10. The procedure described in the preceding paragraph can be reversed should either of the other quantities be required.



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